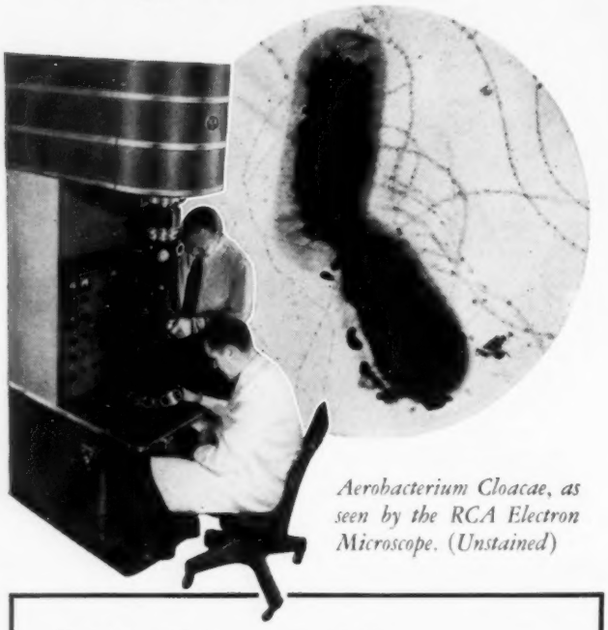
NEW WORLDS —infinitely small!



Aerobacterium Cloacae, as seen by the RCA Electron Microscope. (Unstained)

RCA Electron Microscope
gives 50-Angstrom Resolution

MAKING VISIBLE objects whose very existence could previously only be surmised by indirect evidence, the RCA Electron Microscope has opened up new avenues of research in virtually every field of science. Already, laboratory workers have impressed on a photographic plate the details of a *filterable virus.* Valuable information in many fields of *industry,* too, has been gathered by this great research tool. *New* products and processes have already become realities through its aid.

New commercial model of the RCA Electron Microscope is compact and easily installed—and well within the budget of virtually any laboratory. Magnification is variable from 1500 to 30,000 diameters in ten electrically-controlled steps: further enlargement photographically gives up to 100,000 useful diameters. Voltage is variable from 30,000 to 60,000 volts for varying penetrations of the specimen.

The RCA Electron Microscope comes equipped with power-supply and controls in a single integral unit, and with two compact mechanical vacuum-pumps...and takes its power from any ordinary 110-volt, 60-cycle, single-phase A. C. line.

Complete descriptive data and literature are available on request

RCA

Engineering Products Division

RCA Manufacturing Company, Inc., Camden, New Jersey
A Service of the Radio Corporation of America
In Canada: RCA Victor Company, Ltd., Montreal

Instruments
THE MAGAZINE OF Measurement and Control

Vol. 14 **SEPTEMBER 1941** No. 9

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Courtesy Taylor Instrument Companies
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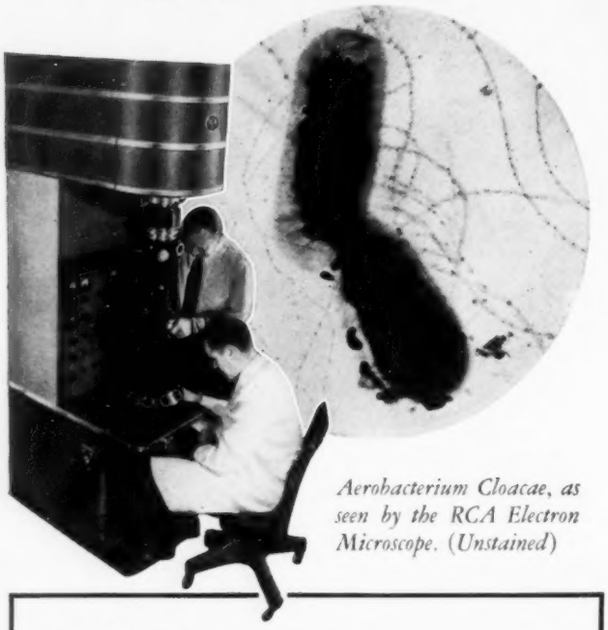

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Next Two Issues "Specials"

AVIATION instruments—not only aircraft instruments but shop and laboratory instrumentation for production, inspection, research, testing, maintenance and service—will be the theme of our October issue. Articles have been (and are being) written by eminent authorities in aircraft companies, engine companies, universities, research laboratories, etc. The October issue will also include articles on education and training in various subjects from the mathematics of instrument design (M.I.T.) to efficient servicing and repair (various special schools).

LEVEL CONTROL—not mere indication but automatic control—will be the theme of our November issue. Half a hundred makes of controllers will be described—just as sixty-odd makes of time controllers were described in last June's special issue on that subject.

Chicago Sets Example

CONGRATULATIONS to the Chicago Society for Measurement and Control! In late August they had already made up and printed a complete program for all their meetings to next May (see page 270). The sincerest tribute we can pay them is as follows: We used to urge readers to organize local societies of instrument men and to write here for advice; but now we recommend that readers thinking of starting local groups get in touch with Earl Rieger, Bill Douglas, Carl Hope and the other C.S.M.C. officers and committee chairmen.

"Defense Production Gaging"

IS the title of another serial which *Instruments* publishes as a contribution to National Defense. Like the serial on electrical-instrument servicing, it is being written from month to month. It is not a re-hash of old texts, because the old texts are no longer usable. It is up-to-the-minute! One thing that makes it especially valuable is that it is being written by Rush Bowman, a young civilian gaging-practice specialist who became an Army Ordnance gaging-practice specialist and is teaching classes composed of the following:

(1) Civilian engineers doing Defense work in private industry;
(2) Reserve officers employed as civilians by firms engaged in Defense production;
(3) Reserve officers not called to active duty but working as civilians for the Ordnance Department;
(4) Ex-Reservists now Army officers on active duty.

Another thing that makes Rush Bowman's book especially valuable is that he is writing it

{ *neither* as Mr. Bowman *nor* as Lieutenant Bowman }
{ *both* as Mr. Bowman *and* as Lieutenant Bowman. }

In other words, the serial is the substance of his classroom lectures: nothing secret, but a lot of "practical dope" not found in the ordinary gaging handbooks or in the telegraphically-brief official instructions issued by the Army. Your editor, as a Reserve officer, attended lectures scheduled to be given by "Lieutenant" Bowman. We found to our delight that the lecturer dropped all formality, especially when answering questions, and drew generously upon his practical experience. We learned more about certain topics in a few minutes than we had learned in our years of work in precision-instrument shops. We immediately resolved that our readers should be let in on these pearls of wisdom. Red tape was cut (with such ease that we can tell you there's no red tape in the 1941 teamwork of Army and Industry) and . . . Bowman's first chapter is in print!

Salute the Ordnance Department!

BUT although Bowman is a born teacher and expounder, his book is not entirely "his"—it is, in a broad sense, but one of the thousands of benefits accruing from the admirable Industrial Preparedness activities carried on untiringly by the Ordnance Department of the Regular Army during the twenty years that the American people slept. Many *Instruments* readers know the more spectacular activities: metallurgy, ballistics, explosives, special-purpose automotive vehicles, etc. Few are aware even of the existence of the Gage Section. By a fortunate coincidence, the story of the Gage Section, written by its brilliant Chief, Lieut.-Col. Harry B. Hambleton, is appearing in *Army Ordnance**. Selected portions of this article would constitute such an appropriate *Instruments* editorial on the subject that we "yield the floor" to Col. Hambleton (after writing a title of our own):

Army's Foresight Prevents Inspection Bottleneck

IN times of emergency the functions of the Gage Section, Office of the Chief of Ordnance, consist in administration and coördination of all matters pertaining to inspection gages,** gaging, and interchangeable mass production. To accomplish this, subdivisions of the Section are maintained at all manufacturing arsenals.

The engineering and gage-checking groups of the gage sections at manufacturing arsenals, previous to and during the present emergency, have met the increasing demands of an almost insurmountable task of designing, procuring, and checking the necessary gages for this vast program. To the loyalty and energy of the personnel of these organizations much credit is due.

As a heritage from the last war, the Ordnance Department collected at the various arsenals half a million gages which were checked for accuracy and stored. Many of these gages have been reworked and are being used in our present program. On completion of this task, it became the function of the Gage Section to design, procure, and maintain new gages for the inspection of new and revised weapons from a yearly congressional appropriation of

$50,000 to $75,000 between 1925 and 1933, and
$30,000 to $180,000 between 1934 and 1938.

The year 1939 brought the expenditure up to $720,000 as a beginning of the requirements for expanded national defense.

In 1940, to meet increasing defense demands, a yearly expenditure of over $1.000,000 was made.

In 1941, $6,380,864.67 was expended under the national-defense program for gage design, procurement, maintenance, gage laboratory equipment, and supplies.

In 1942, it is expected that considerably more funds will

*Vol. XXII, No. 128, Sept.-Oct. 1941, pages 203-212. Published by the Army Ordnance Ass'n, 705 Mills Bldg., Washington, D. C.

**For distinction between inspection gages and manufacturing gages, and other definitions, see Bowman's article, pages 252-254.

be needed to meet gage requirements of the anticipated Ordnance production program. . . .

Concurrent with these functions, constant contact was maintained with industry, the American Gage Design Committee, the National Bureau of Standards, the American Standards Association, the Air Corps, and the Navy in the interest of development and standardization of gaging methods and gages to simplify and improve interchangeability and mass production. . . .

The fruits of these efforts are evident in the uniform standardization throughout the gage industry which has been a factor in the present emergency in expediting our production program. . . .

Realizing the necessity of trained personnel for duty in times of emergency, the Ordnance Department organized an educational program to prepare civilians for work in the arsenal gage laboratories and gage design sections as well as officers of the Reserve Corps who were qualified by education and experience for duties in gage sections and laboratories in Ordnance districts. These officers were given

Navy Day is September 27, birthday of Theodore Roosevelt who prophetically built it up in peace-time, but now that it is actively defending our vital rights, every day is the day of the United States Navy—which *Instruments* serves quietly and hereby salutes.

courses of instruction at the arsenals and leading engineering schools of the country from year to year during 14-day periods of active duties. They were trained not only in gaging but also in the duties of an Army Inspector of Ordnance—one of the most responsible jobs in the Ordnance Department. Today, in a time of national emergency, the reward of this work is being reaped. Our district and arsenal laboratories are in the hands of trained and experienced men, and our manufacturing plants have reliable Ordnance Inspectors under competent supervision. As a result, the closest adherence to specifications has been achieved. . . .

The manufacturer [of Ordnance items] works to the *component tolerance*; the gage maker works to the *gage tolerance*; and the gage laboratory must measure to an accuracy that is *a small fraction of the gage tolerance*. The precision measurements of the gage laboratories are transmitted to the component by the Inspector.

Nineteen Ordnance gage laboratories* have been established in the manufacturing arsenals and Ordnance procurement districts. The foresight of the Ordnance Department in equipping these laboratories in the years prior to the emergency can be seen in the serious bottleneck which has developed in the supply of precision measuring equipment due to the restriction of foreign sources of supply and the long period required to manufacture precision equipment. Nine of the district laboratories were set up in universities between 1930 and 1939. They were used for training purposes before the emergency and were placed on activated status in 1940 by the districts.

The standards of all Ordnance gage laboratories are precision gage blocks, calibrated at the National Bureau of Standards by interfereometry methods. Arsenal and district gage laboratories are air-conditioned to provide the international standard measuring temperature of 68°F. (20°C.) and humidity is controlled to prevent corrosion of gages and instruments.

The arsenal gage laboratories are responsible for the initial checking and acceptance of the vast quantities of inspection gages that are being procured. The results of their efforts . . . as of June 1, 1941 . . . sufficient gages were on hand . . . to insure that *inspection operations were not delaying production*. Optical projection gaging methods developed at Springfield Armory have contributed speed and accuracy to small-arms inspection with a resulting increase in production.

The district laboratories are responsible for the constant dimensional surveillance required to detect worn or damaged gages. The huge production scheduled for the fiscal year 1942 will place a heavy load on the district laboratories as they must insure that the gages used by inspectors are functioning properly at all times. Many of the contractors engaged in the production of ordnance items lacked the necessary measuring equipment and experience required for interchangeable manufacture. The district laboratories have made a valuable contribution toward production by providing precision measurements on manufacturers' gages so that the contractor could proceed with production with an assurance that his dimensional control would meet Ordnance inspection requirements. . . .

In normal times, the gage production capacity of this country is $4,500,000. . . The problem was presented to Brig. Gen. H. K. Rutherford in the Office of the Assistant Secretary of War, and to Mason Britton of the Office of Production Management. They enlisted the services of S. B. Terry, of Pratt & Whitney, as an expert consultant to survey the capacity of the gage industry and correlate it with the demand for gages created by the national-defense program. It was found, as a result of this survey, that the total gage requirement of the national-defense program, including Army, Navy, and Air Corps needs, would be $16,000,000 . . . it was decided to expand four of the gage companies; namely, Sheffield Corporation, Pratt & Whitney, Greenfield Tap & Die Corp. and Taft-Pierce Mfg. Co. Since by doubling the capacity of these four companies a $5,750,000 increase in capacity could be realized, the Assistant Secretary of War was advised of this possible solution. He at once obtained funds for expediting production and secured the approval of the Coördinator of National Defense Purchases. On October 15, 1940, President Roosevelt approved the project, and negotiation of contracts was started by the Ordnance Department. The contracts were signed on November 30th, and work was immediately begun on the construction and tooling of additions to the plants of these four companies. [Since then it became evident] that greater expansion of the industry was necessary. After careful consideration contracts were negotiated and signed with the Standard Gage Co., Modern Tool & Die Co., and John Bath & Co. These new plants, veritable toolmakers' paradises, are now in production, and the results of the expansion are apparent in the increased deliveries being made.

To meet further demands caused by new programs, the Ordnance Department has undertaken the enlargement of twelve other gage-making concerns strategically located throughout the country. With the completion of this expansion, it is hoped that the gage capacity of the nation will be sufficient to handle the current demands of national-defense production and also to provide gages for the future.

*See description of the New York district gage laboratory by its chief, Major C. DeZafra, *Instruments*, May 1937, page 135.

Coördinated Instrumentation for Moisture-content Control

(See front-cover photo)

AFTER tobacco is aged in hogsheads, bales, or cases, moisture must be added to the matted leaves to permit their separation, removal of stems, and other handling with minimum breakage and scrap. By means of the Guardite Tobacco Ordering Process the proper moisture can be added to the product uniformly throughout any container not hermetically sealed in a period of 30 to 60 minutes instead of the ten days to two weeks previously required in a sweat room. An ingenious application of Taylor temperature, pressure, and vacuum instruments, the functions of which are coördinated by "Flex-O-Timer" time-cycle controllers, controls the sequence of vacuum and steam injection to the treating chamber; and delivers the tobacco within 0.25% of the required moisture content. The system is automatic, yet any cycle can be modified at will to produce any desired result. It releases labor for other tasks and reduces the cost of moistening to as low as 15 cents per ton. This month's front-cover photo (courtesy Taylor Instrument Companies) shows an installation of the system at the plant of the American Tobacco Company, Reidsville, N. C. Similar systems are available for treating foods, chemicals, and textiles as either raw or finished products.

THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

L-f. Linear Time-base Generator for C-R-O

New "Type 215" low-frequency linear time-base generator is especially suitable for studies of low-frequency phenomena such as found in vibration studies, strain analyses, physiological applications, etc. New generator has a frequency range from 0.2 to 125 c.p.s. with negligible deviation from absolute linearity. It offers both single and continuous sweeps controlled manually or by positive signal. Maximum undistorted output is 500 volts d.c. Signal blanking facilities are provided. Generator is particularly recommended for use with maker's Types 175 and 175A oscillographs which are provided with long-persistence screen teletrons operated at high accelerating potential. Housing is maker's standard portable metal case with leather carrying handle. Dimensions, 14"x8"x17¼". Weight, 35 lbs. —*Allen B. Du Mont Labs., Inc. 2 Main Ave., Passaic, N. J.*

Tiny Transformers

For aircraft apparatus, hearing aids, etc., new 7/16" × 7/16" × 3/4" output coupling units are said to be world's smallest quantity-

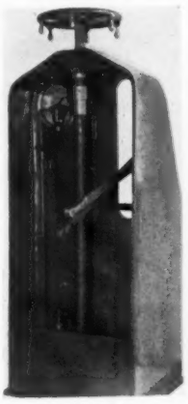
production transformers. Nearly ten thousand turns in coil structure effect inductance of approx. 70 henries. Weight 0.3 oz. —*United Transformer Corp., 150 Varick St., New York City.*

Pulse-rate Recorder

Named after the two Cornell University Medical School professors who developed it, the Parmenter-McLean Cardiotachometer is a new type of amplifier-recorder originally designed for a specialized research but finding application in other fields where its characteristics are advantageous. It is chiefly used to obtain continuous records of the pulse rate under practically any condition. The Cardiotachometer may be used successfully on humans, as well as dogs, pigs, and similar sized animals. The instrument consists of an amplifier peaked at 25 cycles. The heaters of the tubes are operated through a transformer from 110-volt 60-cycle a.c. The plate and screen grid potentials are supplied from a block of standard radio "B" batteries supplying 200 volts. Electrodes about the size of a dime are fastened with electrode paste over the base and apex of the heart. The potentials develop as the heart beats control the output circuit and serve to operate a relay. The relay may be used to operate a counter or a signal magnet on the kymograph and to furnish a record of the heart rate. With the electrodes tightly in place, violent physical action can take place without being reflected to the output in the form of muscle potentials, as the amplifier filters out everything except the impulses desired. Equipment includes electrodes and shielded electrode cable, all necessary radio tubes, relay, and 6 feet of cord with plug.—*Phipps & Bird, Inc., Richmond, Va.*

Hydrostatic Tester for Cylindrical Bodies

Announcement is made of a new testing machine for making hydrostatic tests of cylindrical bodies. Member to be tested is clamped between a stationary seal head in



base of welded frame and screw-actuated seal head. Article being tested is filled with testing liquid by means of a hand pump. Liquid enters body at base and overflows into a cup. Needle valve shown just in front of gage is then closed. Test pressure is then developed by means of the two-pressure hand pump. This pressure is maintained for required time interval. Its value is shown on the flush-mounted pressure gage. Pressure is released by opening the two forged steel valves. Testing liquid allowed to drain back into the sump tank which is built into the lower section of the frame. In order to easily see the leaks in body under test, the liquid may be colored with some dye.—*Dorr-Patterson Engineering Co., 3362 Wright St., Detroit, Mich.*

Surface Plate

Cast in semi-steel and finished to 0.005", new 18" × 96" surface plate has seven support-points for utmost flexibility in use. Two sizes of adjustable blocks or legs (10"

and 12") provide possible working-surface heights between 29" and 33". Blocks support threaded 1½" screws, each topped with a circular cap which is recessed to contain any of the projecting support-points on the bottom of the plate. A 12-pitch thread provides fine adjustment to compensate for floor irregularities, etc. Five of these blocks are provided with each surface plate. Ribbed under side of plate provides strength without excessive weight (surface plate weighs 3 tons). Under side of the plate is painted red, blocks green.—*South Bend Tool & Die Co., 1916 S. Main St., South Bend, Ind.*

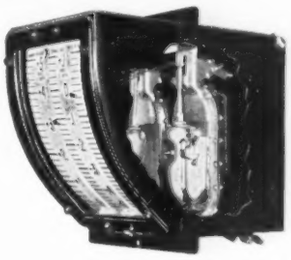
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Bailey Boiler Meter

Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

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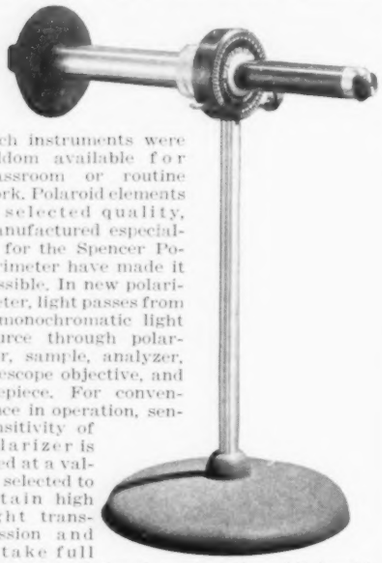
Polarimeter with Lippich Half-shade Polarizer

New Spencer Polarimeter, designed for teaching Polarimetry, for routine laboratory work, and for industrial measurements, employs the Lippich triple field which has long been recognized as the best half-shade device for polarimeters. Because of the high cost of Nicol prisms and of their assembly



such instruments were seldom available for classroom or routine work. Polaroid elements of selected quality, manufactured especially for the Spencer Polarimeter have made it possible. In new polarimeter, light passes from a monochromatic light source through polarizer, sample, analyzer, telescope objective, and eyepiece. For convenience in operation, sensensitivity of polarizer is fixed at a value selected to obtain high light transmission and to take full advantage of the characteristics of Polaroid. Optical rotation of the sample is measured by the corresponding rotation of the analyzer to the point at which the triple field is equally dark. This rotation is accomplished by means of the graduated drum connected to the analyzer by a worm gear. The worm gear may be disengaged by pressing the graduated drum downward. This provides for either hand-rotation or geared slow motion. Main scale is marked in 5° intervals through 360° while the drum is graduated in 0.1°. Marks and numerals are bold and easy to read even in poor light. Removable shield attached to sample chamber shades observer's eyes when matching fields and when reading scales. Removing the polarizer gives access to sample chamber which can accommodate 200mm. or shorter tubes. Chamber itself may be removed. Positioning pins in each end of chamber maintain correct alignment of polarizer and analyzer.

Sample tubes are available in three lengths, 200mm. for general use; 150.3 and 189.4mm. for special sugars. All tubes have enlarged ends to trap air bubbles. Length of sample tubes is controlled to 0.1mm. Molded plastic caps, end windows and washers are interchangeable. Caps engage threads moulded into the glass tubes themselves, thus eliminating all troubles due to loosening of threaded metal sleeves.—*Spencer Lens Co., Buffalo, N. Y.*

Cathode-ray Tube Screens

Announcement is made of availability of different types of screens for cathode-ray tubes, in addition to medium-persistence green screen widely employed because of its high efficiency and the fact that its peak radiation occurs near the peak response of the human eye. Among others are long-persistence green, short-persistence blue, and medium-persistence white. For television (at low image-repetitive rates) there are the Du Mont "memory" tubes with exceptionally-long-persistence effect and now closely approximating white. Long-persistence green is useful for studies of slow transients. Persistence time obtained with any transient increases directly with the accelerating potential at which the c-r. tube is operated, and it is also dependent upon the writing rate of the spot which in turn is determined by the individual signal under study. Long-persistence screens cannot be supplied for cathode-ray tubes having maximum accelerating-potential ratings of less than 3000 volts. Short-persistence screens are generally employed for moving-film recording, to prevent any fogging from trailing the pattern. High actinic value of radiation from screen is also of value for all other photographic purposes. Medium-persistence white screen is used for television picture reproduction at usual picture repetitive rates.—*Allen B. Du Mont Labs., 2 Main Ave., Passaic, N. J.*

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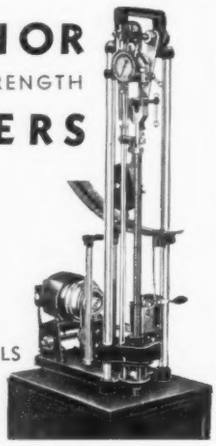
TESTERS
for
PAPER
CORDAGE
RUBBER
LEATHER
WIRE
FLAT MATERIALS



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PAPER FOLDING ENDURANCE TESTER
BURSTING TESTER
MICROMETERS (POCKET and DESK)
PAPER BASIS WEIGHT SCALES
CORDAGE SCALES
ALUMINUM FOIL SCALES
COMPUTING SCALES
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DEAD WEIGHT
PRESSURE GAUGE TESTER
TACHOMETERS
INDICATING and RECORDING
MERCURY COLUMN GAUGES

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438 Fairfield Ave., Stamford, Conn.

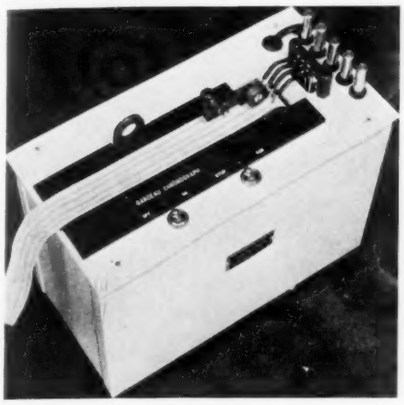
Automatic Control of Feeders on Pulverizing Machines

Automatically controlling the mechanical feeding of pulverizing machinery, new Mosher Automatic Control safeguards against clogging, overheating and motor burnouts arising from overloading because of variations from lot to lot, due in turn to change in moisture content which increases or decreases grindability. Equipment comprises a control unit which connects to the magnetic contactor switch of feeder motor operating mechanical feeder (ranging from 1 to 5 h.p. in usual installation). When control is first installed, an ammeter is wired into the circuit and the grinder motor started. When full load is indicated on ammeter, load range regulator knob is turned to decrease load until red light shows. Control is then set for permanent operation. A special current transformer is supplied, adjusted for normal full load current of grinder motor. (This transformer is the only extra accessory required.) In operation, grinder motor is started in regular manner. Only then can feeder motor (interlocked with grinder) be started. White signal light then flashes to indicate operation of the control. Load range regulator has a range of 50 to 125% of grinder motor full load, so that equipment can be used for a wide variety of materials. Once maximum load is set for a material, however, controller acts as load limiter: If material changes, or if for any reason mill load rises above full-load setting, controller cuts off feeder motor and red light goes on. Mill continues to discharge and mill load will drop to below load point setting, whereupon feeder cuts in again and red light goes off. (A steady red light for more than half a minute warns attendant to investigate.) Green light flashes when mill load drops about 25% below full-load setting: material not reaching grinder, due to an empty bin or arching over mill or feeder. Control panels are built in capacities up to about 250 h.p. on the grinder motor and for about 5 h.p. on the feeder motor. Standard voltages range up to 550 volts, but equipment can be built for voltages up to 2300 on main grinding motors. Control proper operates from 110-volt 60-cycle line.—*Max Mosher, 130 W. 42nd St., New York City.*

(Industrial Instruments, Inc. 156 Culver Ave., Jersey City, N. J., manufacturers of the controller proper.)

Chronograph with Inertialess Marking System

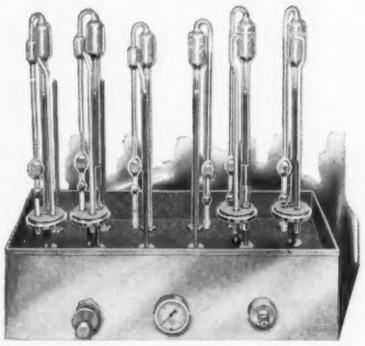
New Garceau Chronograph utilizes an electrically-sensitive recording paper tape, a reel of which is contained within the case. The tape is drawn beneath the styli by a



constant-speed self-starting synchronous motor which provides an accurate speed calibration independently of time signals. A self-contained isolated rectifier system supplies the marking current (a few milliamps.) for the styli. An immediately permanent trace is visible on the dry tape, which requires no processing or developing. Since the styli do not move, and mark only when electrically energized, there is no lag whatever, and extremely precise indications are obtained. Model illustrated uses four styli marking on a 1" tape at a speed of 3 cm./sec. (1.18 in./sec.). Dimensions are 10" × 5" × 7" and weight is 13 lbs. Models with any specified number of recording units and a selection of tape speeds up to 100 cm./sec., are available. All are on a par, in their essentials, with Garceau Chronograph developed in connection with an important Defense project. — *Electro-Medical Laboratory, Inc. Holliston, Mass.*

Cleaning and Drying Apparatus

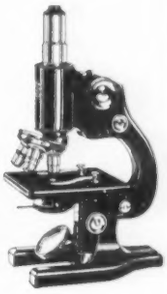
New TAG-A.S.T.M. Kinematic Viscosity Cleaning Apparatus was primarily designed for glass viscosimeters for determining kinematic viscosity. However this equipment is also adaptable for use in connection with



the cleaning of other types of glassware such as test tubes, pipettes, etc. The tubes are placed over and supported by vertically extended metal capillary tubes through which the cleaning fluid is sprayed. Drying is accomplished by passing air under pressure through the tubes. Pressure can be closely controlled and observed. Provision is made for first connecting spray line to vessel containing cleaning liquid. Then by adjusting the valves, air is forced through the tubes. To prevent excessive use of solvent or cleaning fluid, a spring type valve is used which closes when valve handle is released.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Spencer Instruments for Industrial Control

Spencer Stereoscopic Microscopes are used for the examination of details too small to be seen by the unaided eyes—to examine impurities or inclusions in raw materials, flaws or irregularities in materials being processed, surface characteristics of finished products. A vivid three dimensional image is obtained.



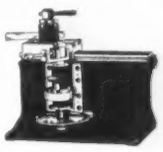
The Spencer No. 33 Microscope is adaptable to almost any type of microscopic examination and is designed for convenience in quickly changing magnifications or types of illumination, for photomicrography, for measuring, counting or examination of materials.

The Spencer Refractometer provides a quick and accurate method for determining the refractive indices of liquids and solids.

The Spencer No. 41 Polarizing Microscope is used for identification of crystalline materials by means of their optical constants.

Direct Result COLORIMETER is used wherever characteristic color is produced proportional in intensity to the concentration of a substance in solution.

The Spencer Microtomes are used for cutting cross-sections of material for microscopic examination of structure, results of processing, etc.



Write Dept. No. W32 for catalogs describing these instruments more completely.

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CO_2 Analysis in a Few Seconds?

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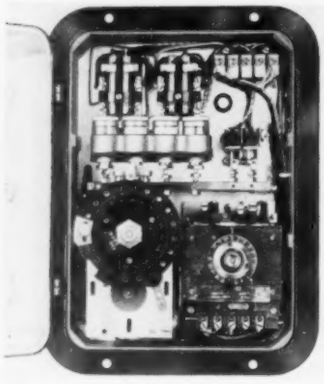
SEND FOR BULLETIN No. 700

CHARLES ENGELHARD, Inc.
90 Chestnut St., Newark, N. J.

Timer for Plastic Presses

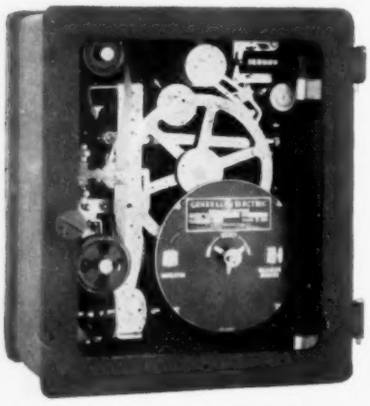
New Model A-127 Single-Cam Cycle Controller, for plastic molding presses, is readily adjustable for different schedules of operation, automatically times from one to four



separate factors and is adapted to applications where these operations follow each other in rapid sequence. Lengths of pre-heating, curing, and breathing periods can be easily changed by the user without changing cams. Timing of the curing period is taken care of by an adjustable timer, which can be set for any length of cure by merely turning a knob. Range of the adjustable timer is zero to 20 minutes with the scale graduated to one second per division. All of the other operations are timed by a cam. The pre-heating and breathing periods are determined by the position of two cam segments, which can be cut to the proper length and positioned on the cam to give the desired schedule.—*The Bristol Co., Waterbury, Conn.*

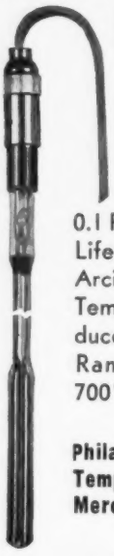
Time-interval Demand-meter Mechanism

New "PD-7" demand meter with built-in time-interval mechanism supplements the "PD-5" (which employs a separately-installed contact-making clock for control of its timing and recording mechanism.) Interval timing mechanism in new PD-7 is of the Telechron synchronous-motor type,



is located on back of meter, and may be inspected easily by swinging forward the hinged grid of the meter. Five terminals are provided so that new meter can be used in combination with the PD-5 where two synchronous records are required, as for "in" and "out" demands of a single installation, or kw. and rkva. demands. In such applications, timing mechanism of PD-7 meter controls printing and reset of PD-5. Interval timing is accomplished in new meter by means of "on" and "off" triggers which ride on two cams. A clutch in timing train of meter permits setting the interval dial in relation to actual time by manual adjustment of a setting knob.—*General Electric Co., Schenectady, N. Y.*

Philadelphia Merc-to-Merc Thermo-Regulators Feature



Mercury to Mercury Contacts : Increased Contact Capacity : Sensitivity within 0.1 F. Exceptionally Long Life and Stability : No Arcing : No Oxidation : Temperature Lag Reduced : Temperature Ranges adjustable to 700°F.

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Philadelphia Merc-to-Merc Temperature Controls and Mercury Plunger Relays

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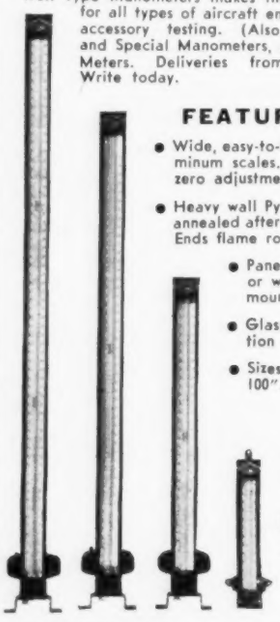


FEATURES

- Wide, easy-to-read aluminum scales. External zero adjustment screw.
- Heavy wall Pyrex tubes annealed after forming. Ends flame rounded.
- Panel, bench or wall mounting.
- Glass protection covers.
- Sizes 12" to 100".

Send for Bulletin No. 60

TRIMOUNT INSTRUMENT CO.
408 S. PLYMOUTH ST. CHICAGO, ILL.

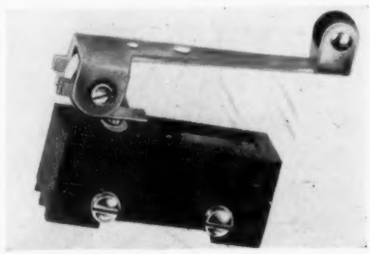
Industrial Timer

New "Duraflex Time Delay Relay" provides time control of motors, valves, gongs or lights; is suited to be built in the apparatus it is to control. It has a 4" diameter dial and time set pointer, also cycle-initiating push button in center of time setting knob. Time settings remain fixed for repeated time intervals until knob is turned to a new setting. Timer can be arranged to hold a circuit open or closed. Ranges are

120 sec. in 1-sec. divisions and 20 min. in 10-sec. divisions in two available models. Units are available in open or enclosed construction for 110 volts or 220 volts, 25- to 60-cycle. Surface mounting cabinet measures $5\frac{3}{4}'' \times 8'' \times 4\frac{3}{4}''$. Depressing the push button disengages a toothed clutch to reset timer. Releasing button closes one set of contacts and opens second set, engages a clutch so that self-starting synchronous motor holds contacts in position during the preset interval. At end of interval, first set of contacts opens, second set closes, and both remain in these positions until another cycle is initiated. Contacts are $\frac{3}{8}''$ diam. by $\frac{3}{32}''$ depth coin silver, open with a snap action, are rated at 10 amps at 110 volts, 5 amps at 220 volts a-c. non-inductive load.—*Eagle Signal Corp., Moline, Ill.*

Roller-arm Actuator for A-c. and D-c. Switches

Said to combine the advantages of $\frac{3}{8}''$ over-travel, large reduction in effective operating pressure, and construction suited to high-speed cam operation, new Type Y



Actuator for Mu-Switches comprises a nickeled steel arm carrying at one end a graphite-impregnated, self-lubricating Bakelite roller and pivoted on an oil-less bearing at the other end. A U spring of phosphor bronze, riveted to the under side of the arm, transmits actuating force to the operating button of the switch and absorbs excess movement at the roller. Actuator may be applied with equal facility to either side of standard Type M (a-c.) and heavy-duty Type D (d-c.) Mu-Switches. It is attached by means of the same screws that hold the switch in place.—*Mu-Switch Corp., Canton, Mass.*

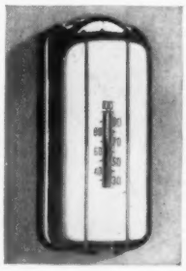
Multi-circuit Self-balancing Indicating Potentiometer

Speed of direct-deflection electrical movement is combined with accuracy of null method in new "Model S Micromax Indicator" which is available with up to fifty

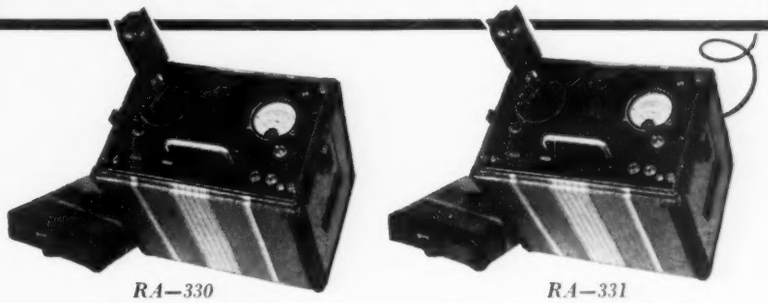
toggle switches on its front. Essentially it is the maker's Micromax strip-chart indicator-recorder minus recording mechanism. Reference-junction compensation is automatic. Occasional standardization against standard cell is performed manually in a few seconds. Toggle-switch handles can be supplied in various colors for easy identification. Moreover, toggle switches can be arranged for thermocouples normally recorded, which are momentarily disconnected from their recorders for indicator readings. No skill at all is required on the part of the operator; only the periodic standardization has to be done by an instrument man. Indicator is regularly available in eighteen iron-constantan ranges and eighteen chromel-alumel ranges; also in any L&N strip-chart recorder range. — *Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*

Demand-compensated Cooling Thermostat

New cooling thermostat, for use in control of unit room coolers, central plant coolers, and individual zones in zone systems, minimizes cost of cooling-equipment operation by obviating need of out-door compensating elements (which previously boosted installation costs and made compensated control for modest installations too costly). A heater element within the instrument produces a difference in temperature between the thermostat and the room, which varies inversely with the percent time on the cooling equipment. This makes possible an automatic and gradual increase in the instrument temperature setting from 72° to 80°F as the outside temperature rises to a point where cooling equipment would normally run full time. This provision for the gradual rise in temperature setting, paralleling the higher outside rise, prevents maintaining too great a difference between indoor and outdoor temperatures — which means less operation of cooling equipment and less danger of temperature shock for persons going from one temperature to the other. New thermostat has electrical ratings of 2 amp. at 25 volts, and 2 amp. at 110 or 220 volts when used with adapter assembly. Net weight 5 oz. Approx. dimensions 4⅝" × 2⅛" × 1¾". Silver-bronze finish makes it suitable for mounting in any surroundings. —*General Electric Co., Schenectady, N. Y.*



TWINS! Two new Sound Level Meters give *greater accuracy at lower cost!*



RA—330
Battery Operated

RA—331
AC—Line Operated

SMALLER, lighter, simpler to operate, these new Sound Level Meters offer you highest quality at much lower cost than previous models. They're calibrated from Bell Labs primary standards—meet A.S.A. specifications—are ruggedly built to assure *lasting accuracy* in spite of hard use.

Features you'll like: Self-contained Calibration Check; Simplified Controls; Feedback Stabilized Amplifier; Moving Coil Mike. New bulletin SP-155 gives complete details. Write to the address below for your copy.

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STOP & GO SIGNALS
are operated by
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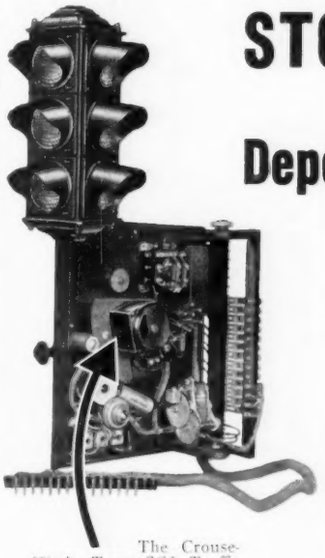


The Crouse-Hinds Type GS3 Traffic Controller operates stop-and-go lights similar to the one shown above. A dependable Bodine Type K synchronous motor was chosen for the important job of driving this unit.

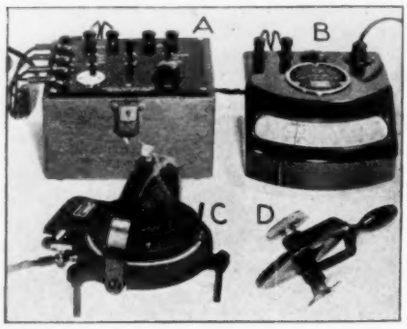
To assure dependable, long-life operation, the Crouse-Hinds Company uses Bodine synchronous motors as the driving unit in their Type GS3 traffic controllers. These motors must operate constantly, day and night, without failure, to keep traffic moving regularly on thousands of street corners.

Bodine motors are applicable to all kinds of instrument drives, because of their dependability, accuracy, and compactness. Fractional horsepower motors, with and without speed reducers, are available as small as 2⅜" square and in ratings from 1/6 to 1/2000 hp. Precision manufacture of all motors assures satisfaction and long life in service. Bodine Electric Company, 2244 West Ohio Street, Chicago, Illinois.

BODINE FRACTIONAL HORSEPOWER **MOTORS**

Fabric Permeameter

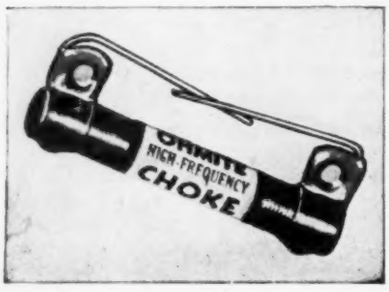
New Fabric Permeameter is for rapid production testing of the permeability of fabrics which are to be inflated with hydrogen, helium, carbon dioxide, etc. Rate of permeation through fabric is quickly determined by equipment utilizing the thermal conductivity method of gas analysis and is indicated in terms of "liters per square meter per 24 hours" of the retained gas. Instrument determines the rate of diffusion, of hydrogen and other gases, through balloon fabrics and other materials, and it enables a testing of the effectiveness of various "dopes" with which the fabrics are treated. Lateral diffusion as well as leakage at seams can be determined by the use of this instrument. Sample to be tested is clamped between two recessed test plates (*C*), thereby forming upper and lower compartments separated by the fabric being tested. Plates keep fabric from sagging and thus ensure identical volumes of the two



compartments. Upper compartment is filled with clean dry air. Hydrogen is passed into the lower compartment. The hydrogen which permeates through the fabric contaminates the air in the upper compartment and thus changes its thermal conductivity. Rate of contamination is a function of permeability. Metering unit in test plate assembly *C* is connected through control box *A* to portable spot galvanometer *B*, calibrated to read directly in hydrogen leakage in "liters per square meter per 24 hours." To prevent leakage of the gas along the layers of textile, and to determine accurately the area being tested, the sample is prepared for the test by being clamped between two co-axial metal disks (*D*) and the edge dipped into a hot sealing mixture. Manufacturers of fabric for lighter-than-air craft, life rafts, life jackets, gas masks, etc., as well as rubber manufacturers and producers of lacquers and chemicals for impregnating textiles, are especially concerned with fabric permeability. However, Fabric Permeameter has applications not connected with National Defense, such as determining the quality of coverings for tennis balls or the suitability of new materials for packaging tobacco products, foods, etc.—*Cambridge Instrument Co., Grand Central Terminal, New York City.*

2½-meter R-f. Plate Choke

New "ZO" 2½-meter band r-f. plate choke is single-layer wound on a low power factor steatite tube; winding is covered with a moisture-resisting insulating material. It is said that there is no possibility of the winding collapsing under operating or overload currents. Also, because of the single-layer winding, voltage differential between adjacent turns is low and possibility of breakdowns between turns is eliminated. Design is such that no portion can resonate independently of any other portion to cause energy absorption at fundamental or harmonic frequencies. Dimensions 1¾" × ¼" tube diam. Mounting is by means of the wire leads. Other sizes available are for the 5-, 10-, 20-, 40-, 80-, and 160-meter bands.—*Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*



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29 ranges in less space than any near equivalent combination—size 12" x 8" x 6"

RANGE OF MEASUREMENTS

D.C. 1 microampere to 1 ampere
20 microvolts to 1000 volts
A.C. (up to 3000 cycles)
2 milliamperes to 3 amperes
60 millivolts to 1000 volts
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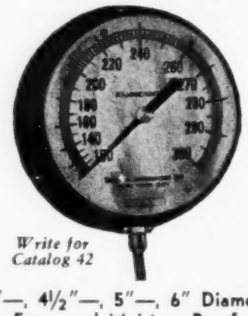
Temperature Instruments

DIAL THERMOMETERS



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3½"—, 4½"—, 5"—, 6" Diameters, Dust, Fume and Moisture Proof, Wall or Flush mounted.

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DEPENDABLE STABILITY
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RHEOSTATS
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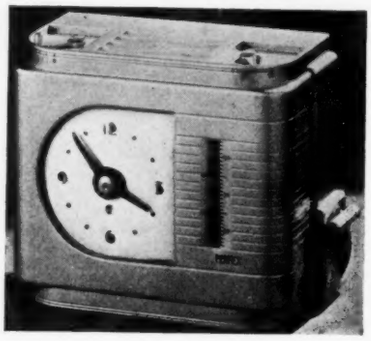
National Electric Controller Co.
5305 Ravenswood Ave., Chicago, Ill.

Clock Thermostat

New heating control unit combines an electric clock and a day-night "Twin Contact Magic Dial" type room thermostat. Day-night controlling circuits are switched



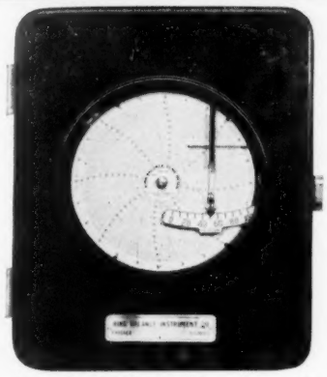
at desired times by a switching mechanism operated by the synchronous electric clock. Day temperature is set in usual way on temperature scale; night temperature is set by adjusting the night set-back lever to number of degrees difference. Day and night change-over times are established by day and night dials, each graduated in hours, and an indicator on clock face shows whether operation is on day or on night control.—*Perfex Corp., 500 W. Oklahoma Ave., Milwaukee, Wis.*

Multi-range Tester

Because it has least possible number of controls, new "Series 834 All-purpose Tester" combines thirty-one ranges in small dimensions (not given in inches but said to

be "no bigger than a man's hand"). Ranges of 0-12/60/300/600/1200/6000 for a-c. and d-c. volts and for output at 1000 ohms per volt; 0-1.2/12/60/600 milliamps; also three resistance and six decibel ranges. All connection (except 1200 & 6000 volt ranges) lead from two pin jacks. Indicating instrument is a 400-microamp. movement; multipliers are said to be accurate to 1%; tester is self-contained.—*Precision Apparatus Co., 647 Kent Ave., Brooklyn, N. Y.*

FLOW METERS FOR ALL PURPOSES



Model 662 Indicating, Recording and Integrating Flow Meter

★

HIGH PRESSURE METERS
Standard Differential Range—20″ to 150″ Water

LOW PRESSURE METERS
Standard Differential Range—1″ to 8″ of Water

★

Range Change Can be Made Without Taking Meter Out of Service

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TEMPERATURE MEASUREMENTS

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Model 70-PO

Pat. Pend.

Portable—Mirror Scales

Save engineering and supervisory time, FOLLOW temperature changes, enjoy greater convenience. No wonder this instrument is specified for automotive, appliance, aircraft, laboratory, metallurgical, process, and many other applications. Write for Bulletin 540-70-PO.

Your inquiries on prompt delivery of indicating pyrometers (including reasonably-priced 3″ COMPENSATED type), thermocouples, and selector switches are welcomed.

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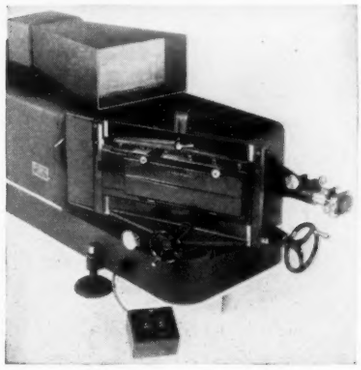
441-J CHAPEL ST. NEW HAVEN, CONN., U.S.A.

Two-lens Quartz Spectrograph

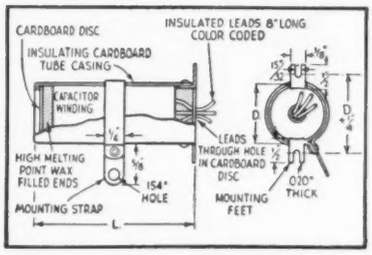
New "L254," a large two-lens quartz spectrograph with Cornu prism, is offered as "the finest quartz prism instrument available." It is recommended for applications requiring highest quality spectra, greatest quantitative precision, and widest flexibility. Two-lens design assures that the light beam follows the most favorable path. The lenses are both centered with respect to, and perpendicular to, the chief ray. No opaque body is placed over any portion of the lenses. Optical excellence of this system gives utmost clarity, freedom from fog and streaks, and exquisite resolution and sharp focus of the spectrum lines, particularly at



ends of plate. Among major features are the following: (1) Only one plate necessary for a complete qualitative analysis in most cases. (2) Only one major control, a handwheel, automatically and simultaneously sets the wavelength, focuses the lenses, and tilts the plateholder. (3) Continuous wavelength setting, whereby any spectrum line can be brought to the center of the plate by merely turning the handwheel. (4) Actual wavelength to which instrument is set, and wavelength range covered by the plate, are projected in numerals 1″ high on a large ground glass screen near operator. (5) Parts arranged for maximum convenience and easiest assembly. Slit is at front of instrument, projects well outward, is therefore always in clear view and readily accessible. Illuminating bench is easier to align because it is in line with optical axis, and customary external right angle prism is avoided. — *The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, Ill.*

Universal Mounting Capacitor

Problem of mounting capacitors, particularly of by-pass and filter units of higher values where size and weight make support by their own leads impractical, are minimized by universal mounting arrangement which forms part of new "Type EZ" dry electrolytic capacitors. Conventional mounting strap around center is supplemented by a pair of slotted feet at one end. "Type EZ" units are available in single, dual, triple and quadruple section units and in wide variety of capacity and voltage ratings.— *Cornell-Dubilier Electric Corp., South Plainfield, N. J.*



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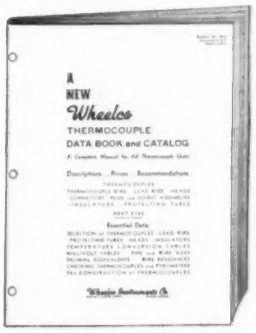

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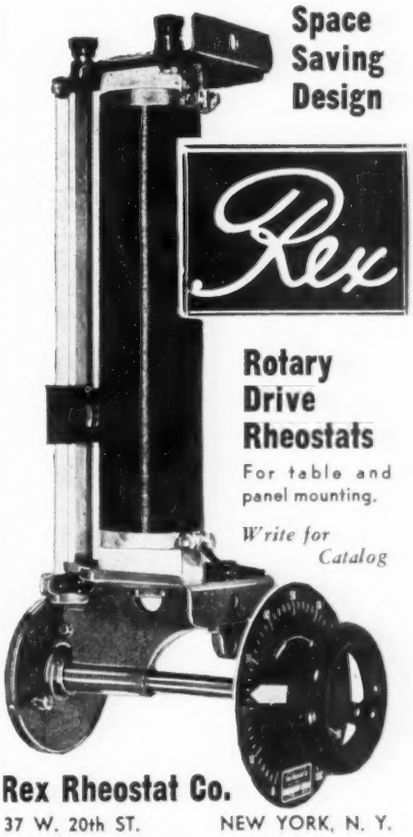

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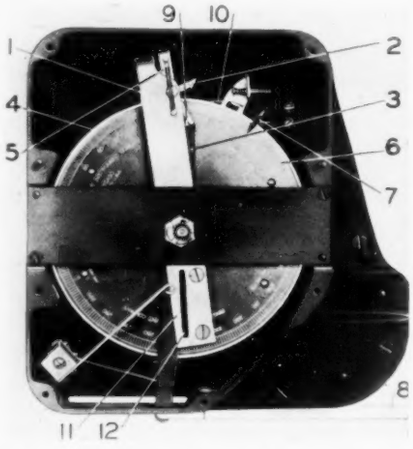
New Type of Integrator for Flowmeters

A new type of integrator will henceforth be incorporated in maker's line of fluid meters (see *Instruments*, July 1941, page 195; August 1941, page 223). In most standard models the electric clock for driving the integrator mechanism forms a part of the gear train assembly. Latter is attached to the follower plate, below the integrator, and simultaneously rotates the chart. Drive to integrator is through chain and sprockets.

In some models, electric clock is mounted on front cover and drives the integrator mechanism directly. Principal parts and their functions: *Time Cycle Link (1)* is a U-shaped stamping so arranged that it straddles index wheel assembly (4) and carries the pawl assembly (2). Link (1) is caused to oscillate back and forth in a rotary motion around the common shaft center for all these sub-assemblies. Four complete oscillations per minute standard; more frequent oscillations can be furnished. Lower ends of the U are equipped with counterweights (11) to form a balanced assembly. One counterweight is slotted (12) to take the crank (not shown) which, by its rotation, imparts oscillatory motion to the time cycle link. *Pawl Assembly (2)*, carried in the closed end of time cycle link, consists of two parallel rotatably-mounted hardened steel pawls and a toggle mechanism (5). Both pawls are mounted on the same shaft; their profiles are identical and they are kept aligned. Both, however, can act independently. *Index Lever (3)* is a U-shaped piece coaxially mounted with the time cycle link and the index wheel assembly. Open end of the U is located at top and each leg carries a trip-pin (9) near its extremity. Lower portion of index lever (the closed part of the U) carries an extension in which is the pin whereby index lever and follower



link of meter are connected by connecting link (8) so that position of former corresponds to that of the penarm. Index lever position, therefore, corresponds directly to the rate of flow as measured by the meter. *Index Wheel Assembly (4)* consists of two parallel coaxially mounted ratchet wheels separated by a thin spacer disk. Each wheel is 6⅛" in diam. and has 900 teeth. The two wheels and the spacer form a single unit and the teeth of one wheel are offset by one-half a tooth from those of the other wheel. Since the two pawls are not offset, this gives the equivalent of 1800 teeth. When integration is in process the index wheel assembly is rotated through 120° (600 teeth) for 100% flow reading. Thus a movement equivalent to 6 teeth corresponds to 1% of the flow reading. In terms of accuracy, limit of error here is 1/1[illegible] of 1%. Graduation of 6" diam. dial (6) corresponds to equivalent percent flow readings. This dial enables checking the integrator which the meter is operating. A window in the front cover permits motion of index wheel assembly to be read by reference to stationary index pointer (7).

Sequence of Operation. Time cycle link (1) rotates clockwise and at the end of its stroke a stop pin attached to the housing trips pawl assembly (2). Pawls drop onto the stripper plate (10). As time cycle link (1) rotates counter-clockwise, pawls ride stripper plate until the point is reached where integration commences. At this point a pawl (2) engages a tooth of index wheel assembly (4), and as time cycle link (1) continues to move, index wheel assembly (4) is rotated. Integration is now in process. The integration continues until the trip-pin (9) of index lever (3) is engaged by the toggle trip-lever and the pawl assembly (2) is disengaged from index wheel assembly (4). Rotation of index wheel assembly (4) is transmitted to the cyclometer counter through a gear and pinion as shown in photograph. Note that the pawls and teeth of the index wheels are engaged *only when integration is taking place.* There is no rubbing of the pawls upon the ratchet teeth, therefore, no wear. The only adjustment consists of moving the stripper plate in or out, as needed, until the correct reading is obtained. — *Ring Balance Instrument Co., 740 N. Franklin St., Chicago, Ill.*

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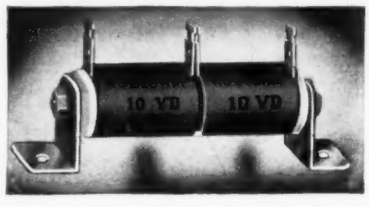

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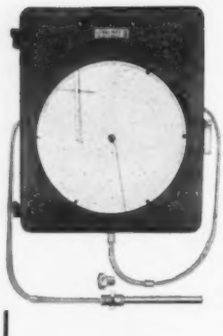

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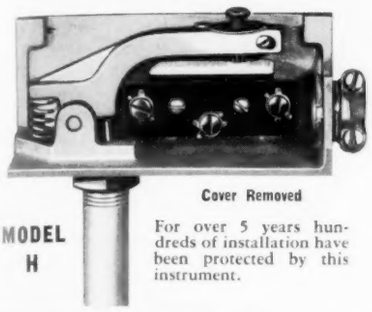

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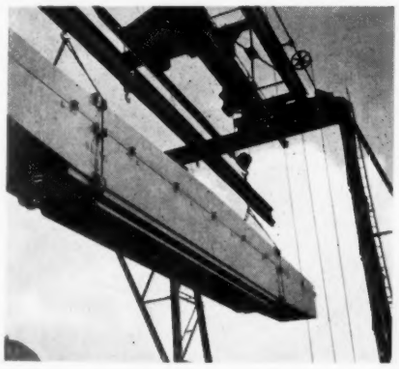

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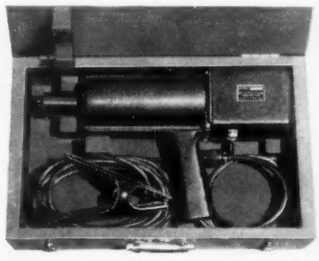
and ceramic end-spacers are also supplied. Several resistor sections can be connected in series and be mounted on the same tie rod and mounting feet with a similar assembly insulated from it electrically by means of the ceramic spacers. Overall length of 10-watt Type VD Koolohm is 1⅛", diam. ⅝", 15-watt sections 1 9/16" long × 11/16" diameter. — *Sprague Specialties Co., North Adams, Mass.*

Bond Testers

Two models of a new Electric Bond Tester are announced, for measurements of low resistances—small fractions of an ohm—those usually determined in the laboratory by the Kelvin bridge method. Both models may be operated by persons lacking the technical training required for operation of laboratory bridge apparatus. They have been brought out for production testing in



plants manufacturing electrical equipment, for quickly testing the effectiveness of electric bonds in airplanes, land vehicles, etc.

"*Aero-Gun*" model (illustrated) has pistol grip and probes extending from "muzzle" end for rapid operation by one worker without assistance. Battery is in handle; indicator and control equipment in "butt" end. It weighs 5¼ lbs. and is 12" long overall. No. 663 has ranges of 0.003 and 0.3 ohm; No. 665, 0.005 and 0.5 ohm. Accuracy is ± 3% at full scale.

"*Milli-Ohm-Meter*" model has conventional rectangular case (10" × 10" × 6½") and weighs 7¾ lbs. It is available in several single-range and multiple-range styles.

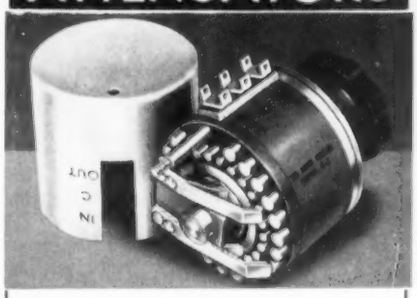
Also available is a *Test Standard* (0.0025 ohm) for periodical checking of the new bond testers and of other low-resistance measuring instruments. — *Shallcross Mfg. Co., Collingdale, Pa.*

Stop Clock

New "Secron," a 36-hour stop clock, though said to "cost less than the usual stopwatch repair job," is said to be com-

parable in accuracy to stopwatches costing three to four times as much. Illustration shows principal features.—*Burrell Technical Supply Co., 1936 Fifth Ave., Pittsburgh, Pa.*

DAVEN ATTENUATORS



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Defense Production Gaging*

By RUSH A. BOWMAN

DURING 1936 and 1937 Mr. Bowman was employed by the Harrisburg Steel Corporation where he was in charge of gage surveillance and inspection in the coupling shop of that company. In 1938 he received from the University of Michigan the degree of Bachelor in Engineering; and a Reserve Commission in the United States Army Ordnance Department. From the time of graduation until called to active duty in September 1940, he was associated with Fuel Savers Inc., Harrisburg, Pa., as a heating and ventilating engineer. At the present time he is on extended tour of active duty with the Pittsburgh Ordnance District of the United States Army in charge of the District Gage Control Laboratory at Carnegie Institute of Technology, Pittsburgh. This Laboratory is charged with the surveillance and inspection of all Army gages used in the production of Army Ordnance Defense matériel in the Pittsburgh District. See the editorial on page 241.

CHAPTER I

INTERCHANGEABILITY

When interchangeability is introduced into the manufacture of component parts of an assembled product, any similar part may be placed in its intended position in any assembly, and so placed, will function as intended without the necessity of further machining or fitting.

Absolute interchangeability is a necessity in the manufacture of Army Ordnance items. Consider for example a machine gun defending a strategic position in an engagement which may decide the course of a campaign. A stoppage occurs; inspection discloses that a small metal part is broken; it is quickly removed and the single spare part is taken from the kit and placed in its stead. If this spare part should not fit, the gun is rendered useless and the position vulnerable. Contrast this life-and-death importance of Ordnance items with everyday items such as washing machines, vacuum sweepers and electric fans, the parts of which we consider "interchangeable." When these devices need repair, they are sent to an experienced repairman and if, say, the new bearing which is required needs some polishing in order to make it fit, he has the facilities to polish it—unless he decides to try another bearing.

Interchangeability is dependent upon accuracy in manufacture and accuracy in inspection. Unless it is known definitely that a component part is within specified tolerances, it is impossible to know that it will assemble properly and function as desired. It is of course, impossible to manufacture parts of weapons and ammunition to an "exact" dimension, say a millionth of an inch, but we wish to come as close to perfection as the economy of manufacture will permit. Fig. 1 shows generally the curve governing tolerances. The curve is hyperbolic—going to infinity along both axes—

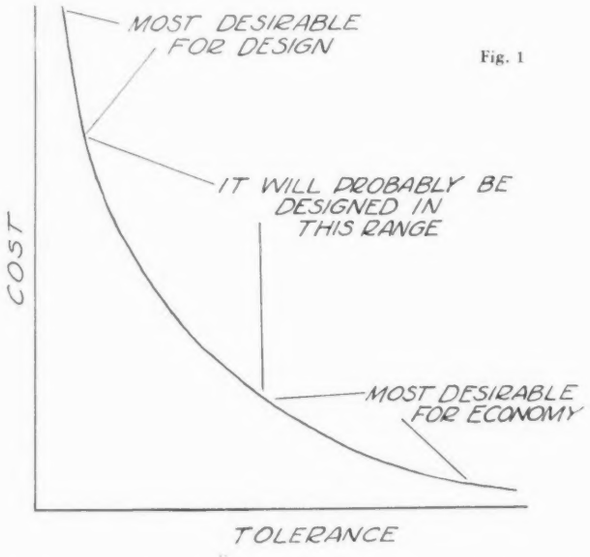

Fig. 1

which means that (1) no matter how liberal the tolerances, some cost will be involved in the manufacturing of an item; and (2) no matter how much we are willing to pay, we cannot make the item absolutely perfect.

Tolerance is the permissible variation in the size or shape of an object.

SELECTIVE FIT

Selective fit is the process of taking advantage of comparatively large tolerances while still maintaining extremely close fits on mating parts. For instance, suppose a 0.001″ fit is desired between a piston and a cylinder of an automobile. This would necessitate accuracy on both cylinder bore and ring size in tenths of thousands. Such a procedure would be expensive because it would place production cost high along the cost-tolerance curve. The method employed is to allow a liberal tolerance on both bore and rings, say 0.005″ on each. Let us suppose that rings will be made from 3.499″ to 3.504″ and cylinder bores 3.500″ to 3.505″. By specialized type of measuring instrument the rings may be separated into groups within 0.001″ tolerances, that is, from 3.499″ to 3.500″, 3.500″ to 3.501″, etc., and the bores classified in the same manner. Now bores from 3.500″ to 3.501″ are assembled with rings from 3.499″ to 3.500″. The result of modern automatic gaging and classifying instruments as used in the automobile industry is 0.001″ fit with all the economy of large tolerance. Obviously such selection and classification would be impossible in the field in an Army unit.

STANDARDIZATION and INTERCHANGEABILITY

Standardization consists of selection, regulation and control (sometimes through test or measurement and usually through comparison with official, empirical, or arbitrarily chosen norms or samples) for the purpose of arriving at uniformity in the distinguishing characteristics of the product.

Uniformity is attained through care in selection or through precision in maufacture within certain established limitations, and with only slight permissible variations known as tolerances. Through rigid adherence to close tolerances, units become interchangeable.

Interchangeability, in common parlance, indicates that all units are "alike," and that any one may be substituted for, or replaced by, any other.

Recognition and careful observance of the principles of standardization yield products which are interchangeable.

* * *

After discussing "standardization" and "interchangeability" with Rush Bowman and others, your editor sought a "standard definition" of the first term, at least, from the American Standards Association. Two weeks passed without reply. We then consulted the highest authority in Pittsburgh. He prepared the foregoing on condition that we keep his name secret; and he added the following note:

"Most of the existing definitions are concerned with *examples* of standardization. The phrase 'distinguishing characteristics' is a generic term which (I hope) covers all kinds of examples—the size and color of an apple, or the copper content of an alloy."

*The views expressed in this article do not necessarily reflect those of the War Department or of any branch of the Army of the United States.

STANDARDIZATION

Standardization and interchangeability should not be confused. Standardization means, in brief, the selection and wide adoption of a particular size or characteristic of an article for all ordinary use. Thus, the standard business letterheads are $8\frac{1}{2}'' \times 11''$ in size though they vary in thickness and grade of paper; the standard Army correspondence paper is $8\frac{1}{2}'' \times 10\frac{1}{2}''$ whether it be tissue or bond; standard voltage for household electrical appliances is 110-120; standard-voltage incandescent bulbs of ordinary wattages have the standard ("Edison") screw base; large standard-voltage bulbs have the standard "mogul" screw base; small bulbs have the standard "miniature" screw base; and finally, low-voltage automobile bulbs have the standard automotive bayonet base. Even when we leave the field of ordinary articles in common use; and consider the ultimate standards, such as the pound, the volt, the inch, the degree Fahrenheit, etc., we find that they originated likewise in selection and wide adoption.

ARMY ORDNANCE TOLERANCE SYSTEM

As previously mentioned, interchangeability is dependent first upon control of manufacture. The first step in the control of manufacture is the establishment of an adequate tolerance system. The following is a discussion of the tolerance system of component parts and of gages as developed and used by the Army Ordnance Department in its manufacture.

A component is any single part of an assembly.

Component Tolerances: Let us suppose that we are going to manufacture a shaft and a bearing of 3″ nominal dimensions—that which is called "a three-inch shaft and bearing." We have decided that the closest fit which should exist between the shaft and the bearing be 0.002″. We have further decided that from the standpoint of economy in manufacture against functioning of the part both the shaft and the bearing are permitted a 0.002″ tolerance in size. The female part is the basic part. Therefore we shall start with 3.000″, the smallest size which may exist in the bearing, as a basic size and 3.002″ therefore as the largest size which may exist in the bearing. Four possibilities now exist in dimensioning this piece. These possibilities are shown graphically in Fig. 2.

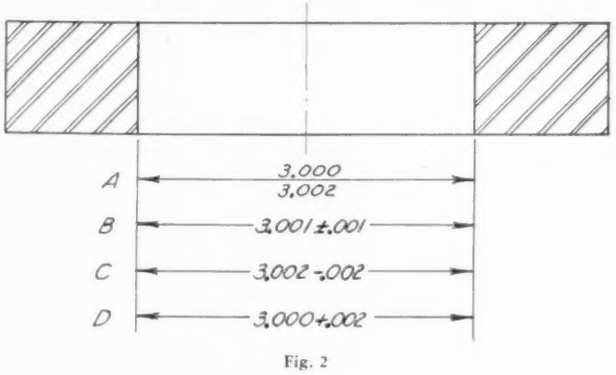

Fig. 2

Three systems are here represented: (A) The limit system which gives the limiting dimensions which may exist in the component; (B) The bilateral tolerance system which shows equal permissible variance on either side of the mean; and (C) and (D), unilateral tolerance systems. Of these three systems, the system used by the Army is the unilateral, and of the two types of unilateral systems shown, "D" would be the one chosen in this particular instance.

"D" is chosen as against the other three types for two reasons:

1. It incorporates as a definite figure the basic size.
2. It incorporates as a definite figure the tolerance.

Basic Size—The exact theoretical size from which all limiting variations are made.

"A" is eliminated because of the second reason shown above. Tolerance should be a definite figure and the use of a limit system requires that calculation be made on the part of the machine tool operator, or the machine tool set-up man. There is no inference in this of lack of ability on the part of the operator, but the elimination of a calculation is the elimination of a possibility for error.

"B" is eliminated because of reason Number 1, in that it does not include as a definite figure the basic size. Psychologically a machinist will work to a shown dimension and in case "B" the shown dimension is 3.001″; but 3.001″ is not the most desirable size for the bearing. The basic size is the most desirable size.

"C" is eliminated also on the basis of reason Number 1.

It is interesting to note that as the basic size is incorporated in the dimension and the tolerance taken in either a positive or negative direction from this basic size, *the sign will represent the direction of the removal of metal.* For instance: as the bearing is bored and measurements are taken, the bearing dimension will increase in size—the tolerance is given as plus.

Allowance: The intended difference in size in mating parts, to allow for functioning of those parts.

Let us now proceed to dimension the shaft. We have stated that the allowance (or the minimum "air space" between

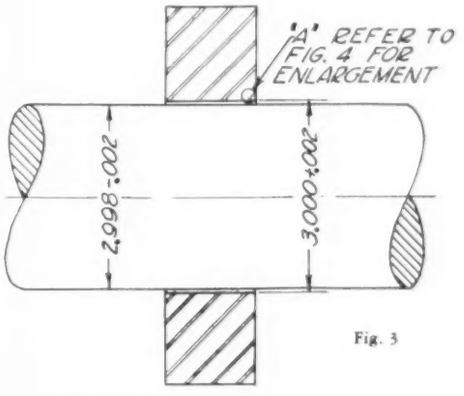

Fig. 3

shaft and bearing) is 0.002″, and therefore the basic, or most desirable size, for the shaft is 2.998″. Now, taking our tolerance of 0.002″, the dimension is written as 2.998″–0.002″.

Fig. 3 shows the completed dimensioning of the shaft and bearing.

MEASURING INSTRUMENTS *vs.* GAGES FOR PRODUCTION

The next problem in interchangeability is the determination that having set up tolerances, those tolerances are maintained in actual production. This control may be exercised in the shop either with measuring instruments or with gages. Measuring instruments of the "shop" grade, up to the present time, have not been widely used in quantity production for the following reasons:

1. They are *normally* more delicate. Compare the physical characteristics of an ordinary micrometer with those of an ordinary snap gage.
2. The use of measuring equipment requires calculation on the part of the inspector, and the elimination represents the elimination of possible errors. Anyone who has used micrometers will remember that he has frequently made an error of 0.025″ (one turn) in reading.
3. Measuring instruments normally require more time in their operation. Recent developments in automatic gages are being used with good results, but the single-purpose measuring instrument such as a micrometer is less suitable than the gage for mass production.

A Gage is a device for determining the relative size or shape of an object. It is not intended that a gage shall actually measure the physical dimension or shape but merely that it determine that the component is within the limits of tolerances.

GAGE TOLERANCES

Having decided upon gages as our method of control, the following is the procedure in their design. The example is our "three-inch shaft and bearing" as above. Let us attempt first to design a "go" gage for the bearing which will permit passage of any piece 3.000″ or larger in diameter. Let us use a plug gage for the purpose. The diameter of such a plug must obviously be less than 3.000″. Such a fit must be dependent upon the quality of the mating surfaces. A ground-and-lapped plug to be inserted in a ground-and-lapped ring must have a difference in diameter of at least 0.0001″. Our bearing will not have such a fine surface and therefore more allowance must be given. This allowance must be determined by experimentation. Let us suppose

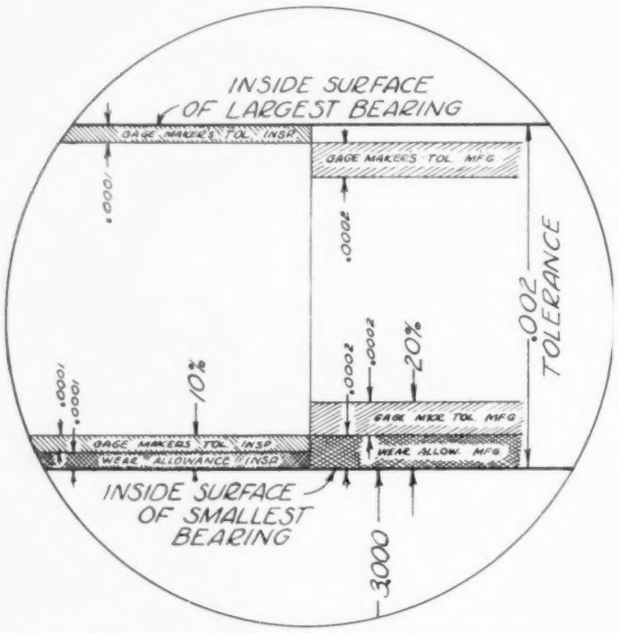

Fig. 4. Enlargement of small circle "A" in Fig. 3, bringing out the meanings and magnitudes of tolerances and allowances.

that we have made such trials and have determined that if our plug is made to a diameter of 2.9996″, the smallest bearing in which this plug may be inserted would be our basic size 3.000″. It must now be granted that although infinitesimal, there will be some wear when the plug is inserted into the first bearing. Theoretically therefore, the second bearing could be smaller by the amount of wear on the gage and still pass inspection. Further, if the bearing should have a more highly finished surface than those on which the 0.0004″ allowance was based, such a bearing might be under the 3.000″ diameter and still pass inspection. Such a system is used by manufacturers where "spot" inspection only is necessary. It is used also in the ordinary standard gages, for instance in a standard 1″ ring and plug the ring will normally be made to 1.0000″ and the plug to .9999″. But it is apparent then that such a system, while comparatively exacting, would be an inadvisable choice in the case of mass production, since constant surveillance is absolutely necessary for maintenance of accuracy.

Since there is to be wear on gages, the Army has adopted the following system for their design:

THE TEN AND TWENTY PERCENT RULES

In order to systematize gage tolerances the Army has adopted the 10 and 20% rule. The 10% rule is followed by the Army in their inspection gages and the 20% rule is recommended for manufacturing gages.

The 10% Rule. Let us now develop the inspection gages for our shaft and bearing. Fig. 4 shows a section of the tolerances enlarged with the inspection and manufacturing gage limits. In order to inspect our bearing for size we will need two plugs, a go and a not go. If we take 10% of our 0.002, that is, 0.0002, we will allow this as the maximum that the inspection gage may vary from the size of the g element. Of the 0.0002, one-half will be taken for wear o the go element and one-half for gage maker's tolerance. Th dimension appearing on the gage drawing would then b 3.0001 + 0.0001. It will be noted that this is a variatio from our original rule on tolerances, to take all tolerance in the direction of the removal of metal. However, we hav not deviated from our two basic requirements of a dimen sional system, and the fact that 3.0001 is the most desirable size outweighs the advantage of the directional tolerance from a psychological standpoint, since the gage maker is highly skilled and gages are not mass produced.

Allowing the same amount of gage maker's tolerance on the not-go element, the resultant dimension for the not-go gage is 3.0020 — 0.0001. The not-go gage has no allowance for wear. Basically there should be no wear on the not-go element of the gage as surface contact is not anticipated in its use. If, however, there is wear, that wear will decrease the tolerance on the component part. For instance, suppose the not-go plug wears to 3.0017, then this gage could be put into a hole of 3.0018 and would therefore reject the part since it is a not-go gage. In like manner it will be seen that the go and not-go inspection gages for the shaft, which in this case will be two snap gages, will be 2.9979 — 0.0001 for the go and 2.9960 + 0.0001 for the not-go.

(This will be true only for a non-adjustable snap gage. Usual practice dictates the use of adjustable snap gages.)

A formula can now be derived to determine the tolerances on gages.

Suppose for example that an outside diameter of a cylindrical part as shown on a drawing is

$$A \begin{smallmatrix} +0.000 \\ -0.a \end{smallmatrix} \text{ inches}$$

Then if $A - 0.a = B$, the maximum limit of the diameter is A and the minimum is B. Let $0.b$ be the wear allowance on the go element of the gage for gaging this diameter and $0.c$ the gagemaker's tolerance. Then the dimensions of a new inspection gage for the diameter would be as follows:

Go element $\quad (A - 0.b - 0.c) \begin{smallmatrix} +0.c \\ -0.000 \end{smallmatrix}$

Not go element $\quad B \begin{smallmatrix} +0.c \\ -0.000 \end{smallmatrix}$

and for a manufacturing gage using the same allowances,

Go element $\quad (A - 0.2b - 0.2c) \begin{smallmatrix} +0.c \\ -0.000 \end{smallmatrix}$

Not go element $\quad (B + 0.c) \begin{smallmatrix} +0.c \\ -0.000 \end{smallmatrix}$

The go element of the *manufacturing* gage becomes unserviceable when it has worn to a dimension equal to $(A - 0.b - 0.c)$.

The go element of the *inspection* gage becomes unserviceable when it has worn to a dimension equal to A.

The disadvantage of such a system is, of course, its inability to accept items which fall in size close to the limiting dimensions. The purpose of gages, however, is to control mass production. Let us suppose that the final operation on the bearing was a reaming operation. The contractor would grind the reamer in order that the first pieces it cut would be close to the 3.002″ diameter. Then, as the reamer wore, it would approach the 3.000″ diameter. The manufacturer's gages made to tolerances 3.0002″ plus 0.0002″ would begin to reject bearings before they became so small that the Army inspection gages made to 3.0001″ plus 0.0001″ would begin to reject them. The tool would then be replaced. Most of the production which was rejected by the manufacturer's gage would still be accepted by the Army gage. A small amount of direct measurement might still be necessary in order that acceptable components (those within the tolerances shown on the drawings) be passed. But thousands of pieces would be manufactured and passed before such a condition began to exist. The gages have therefore controlled production with positive assurance that whatever was accepted was within the dimensional tolerances allowed.

(To be continued)

Maintenance and Servicing of Electrical Instruments

By JAMES SPENCER
Westinghouse Elec. & Mfg. Co., Newark, N. J.

CHAPTER II

A-C. AMMETERS AND VOLTMETERS

One of the first requirements of any repair job is locating the cause of the trouble. For example excessive friction may be due to flat pivots, cracked jewels, fuzz on the coils, dirt in the jewels, damping vane rubbing, etc. In order to analyze the trouble, a maintenance man must have a knowledge of the construction and operating principle of the instrument.

Alternating-current measuring instruments require the same careful attention as direct-current instruments if they are to serve the purposes for which they are designed. Their maintenance and servicing, however, are more complicated because of various factors not found in d-c. work. The great distinction is in the nature of what is measured. As the reader no doubt knows, an alternating current is one which periodically reverses its direction. Fig. 1 may refresh the memory of a few readers.

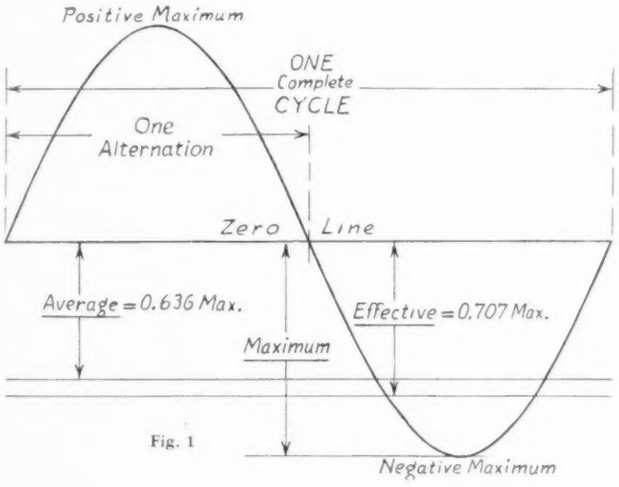

Fig. 1

The various kinds of a-c. instruments to be covered in this series are ammeters, voltmeters, wattmeters, varmeters, synchroscopes, frequency meters, power factor meters, reactive factor meters and phase angle meters.

The instruments to be discussed are those that operate on the dynamometer, moving-iron, induction, electrothermic, rectifier and electrostatic principles.

Nine kinds, and six principles—obviously there are numerous *varieties* of a-c. instruments with which maintenance men should become familiar. At this point, therefore, it may be helpful to refresh one's memory. The following definitions* will help.

ELECTRODYNAMIC INSTRUMENT. An electrodynamic instrument is an instrument which depends for its operation on the reaction between currents conducted to one or more fixed coils. (Also known as an electrodynamometer instrument).

MOVING-IRON INSTRUMENT. A moving-iron instrument is an instrument which depends for its operation on the reactions resulting from the current in one or more fixed coils acting upon one or more moving pieces of soft iron or magnetically similar materials.

*From *American Standards for Electrical Indicating Instruments*, American Standards Association, July 8, 1938.

A Contribution to National Defense

IN normal times it is inadvisable for users of electrical instruments (except users such as utilities with fully-equipped service laboratories) to do any work which involves opening up the case. Before 1941, the only articles on adjusting and servicing instruments which we accepted for publication were on Bourdon gages and other comparatively rugged measurement and control devices. And all we published on the subject of repairs and rebuilding was our stock editorial (reprinted every two or three years) saying "Let the factory do it."

But this national emergency has created a shortage of electrical instruments, so that even plants enjoying priority have to wait. The top shelves of stockrooms are being searched for old instruments. "Irreparable" instruments are being "repaired." And —perhaps most important—all instruments in use must be maintained in good condition . . . by the users. Hence the crying need for this serial—the first and only one of its kind.

A brief biography of James Spencer appeared in our last issue. Since then we had to visit him with regard to future plans; we met him for the first time and discovered that he heads a department of 240 men—a department chock full of ingenious panels, benches, etc., mostly designed by him. —MFB

Note: Various forms of this instrument (plunger, vane, repulsion, attraction, repulsion-attraction) are distinguished chiefly by mechanical features of construction. The above definition is not intended to include the polarized-vane type of instrument which is applicable to d-c. measurements only.

INDUCTION INSTRUMENT. An induction instrument is an instrument which depends for its operation on the reaction between a magnetic flux (or fluxes), set up by one or more currents in fixed windings, and electric currents set up by electromagnetic induction in moving conducting parts.

THERMOCOUPLE INSTRUMENT. A thermocouple instrument is an instrument in which one or more thermojunctions are heated directly or indirectly by an electric current, and supply a direct current which flows through the coil of a suitable direct-current mechanism, such as one of the permanent-magnet moving-coil type.

ELECTROSTATIC INSTRUMENT. An electrostatic instrument is an instrument which depends for its operation on the forces of attraction and/or repulsion between bodies charged with electricity.

RECTIFIER INSTRUMENT. A rectifier instrument is the combination of an instrument sensitive to direct current and a rectifying means whereby alternating currents (or voltages) may be measured.

These will be taken up in this and the next chapters. In this chapter, we deal only with the a-c. ammeters and voltmeters.

A-C. AMMETERS

The amperes or rate of flow of current in a-c. circuits may be measured with instruments operating on the electrodynamic (dynamometer), moving iron (plunger, vane, repulsion), induction (disk, drum) and electrothermic (hot-wire, thermocouple) principles. Since the thermocouple type has been discussed under direct-current instruments, and the hot-wire type is not generally used in modern instrumentation, we shall confine our discussion of a-c. ammeters

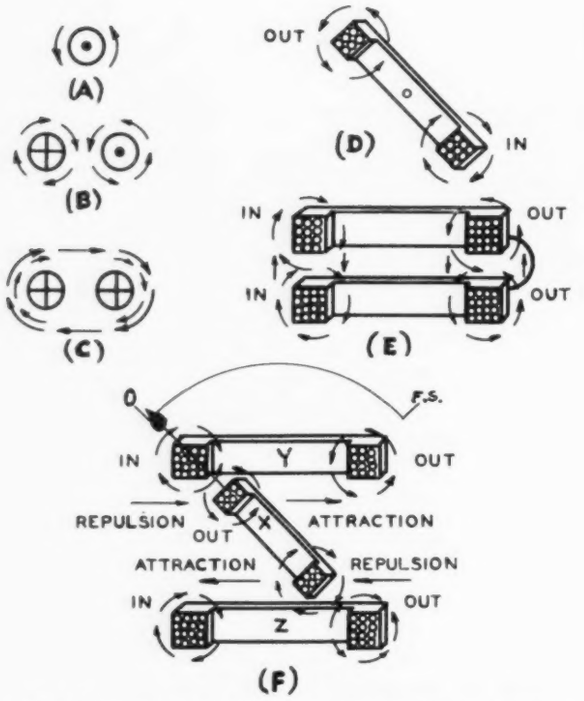

Fig. 2. Operation of the dynamometer type ammeter or voltmeter.

(A) By the right hand rule, a magnetic field flows around a current-carrying conductor as shown (current flowing toward the observer).
(B) Currents flowing in opposite directions in parallel conductors. The magnetic fields oppose each other, forcing the conductors apart.
(C) Currents flowing in the same direction in parallel conductors. The magnetic fields merge and tend to bring the wires closer to each other.
(D) Cross-section of moving coil showing direction of current flow in and out, and magnetic fields produced.
(E) Cross-section of stationary coils showing direction of current flow in and out, and magnetic field produced.
(F) Cross-section of moving and stationary coils connected as in an ammeter or a voltmeter. The direction of current flow is shown in and out; and the resulting magnetic field is indicated as explained above. It can be seen that the pointer will deflect to the right as the coils tend to align themselves in the most favorable magnetic field position.

to the three types most generally used, namely the dynamometer, the repulsion and the induction types.

Operating Principle of the Dynamometer Type

The dynamometer type instrument, due to the problem of conducting current to and from the moving coils, is only used for relatively low current measurements, seldom more than 5 amps. actually flowing through the movement. This type of instrument, however, is widely useful, for it may be used on a-c. or d-c. circuits with equal accuracy since there is no iron in the circuit and therefore a minimum of self-inductance. The electrodynamic principle is applied to modern instruments in two ways: as a modification of the Siemens dynamometer method and as the Kelvin balance method, Switchboard indicating instruments make use of the modified Siemens dynamometer method while the Kelvin balance method is more generally used in portable and recording instruments.

The dynamometer method makes use of the interacting effects of fluxes of two or more coils, one coil being movable (see coil *X* in Fig. 2F) and two coils being fixed (*Y* and *Z* in the same figure). The springs of this instrument serve two purposes: conducting the measured current to and from the moving coil and controlling the moving element. A pictorial explanation of the operating principle is given in Fig. 2.

Reverse readings should be taken on d-c. circuits and reading averaged to eliminate errors due to stray fields.

In the dynamometer type movement the current in the stationary coil produces a field in proportion to the extent of current flow. As a current is applied to the moving coil, the coil moves by reason of the reaction on a current-carrying conductor in a magnetic field. Since the fields of the stationary and moving coils are proportional to the currents in them, and since the moving coil moves in the field of the stationary coil, the torque of the moving coil is proportional to the current in the stationary and moving coils. A forward movement of the pointer depends on the relative polarity of the stationary and moving coils being alike.

It will be noted that the ammeters have an uneven or squared scale distribution. The reason is that since the moving and stationary coils are in series, the torque is proportional to the square of the current being measured.

Operating Principle of the Repulsion Type

Of the moving-iron instruments, the repulsion type is the most widely used today. The principle of the magnetic vane or repulsion type instrument is that like poles repel while unlike poles attract each other (see pictorial explanation, Fig. 3).

The operation of this type of instrument is dependent upon a current carrying coil, two soft iron vanes, one movable and one stationary, and a control spring.

In Fig. 3F we have two soft iron vanes *A* and *B*, one stationary and one movable, attached to the shaft carrying the pointer. When a current flows in coil *C*, the vanes are magnetized. As the vanes are in the same plane, and magnetized by the same source, they are magnetized in the same direction, as in Fig. 3E. Fig. 3F shows vanes *A* and *B* with like poles adjacent and as vane *A* is stationary and vane *B* can move only by rotation, vane *B* would be repelled, causing the

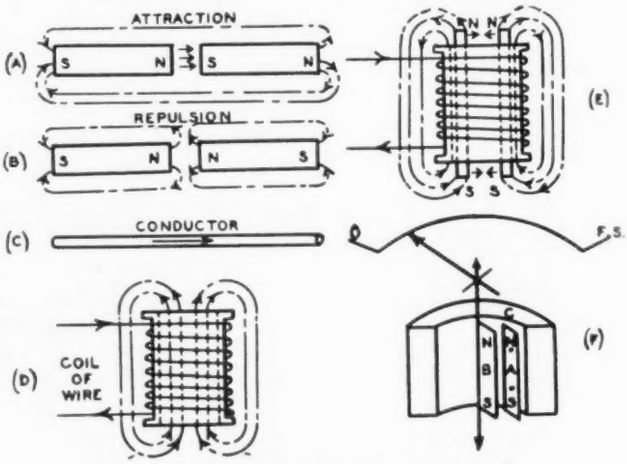

Fig. 3. Operation of the repulsion type instrument.

(A) and (B) The laws of magnets state that unlike poles attract each other and like poles repel each other.
(C) The right-hand thumb rule for a current carrying conductor: Grasp the conductor with the right hand; thumb points in the direction of the current and the fingers indicate the direction of the magnetic field.
(D) The right-hand thumb rule for a coil: Wrap the fingers of the right hand around the coil in the direction of the current and the thumb will point to the north pole of the coil.
(E) Two iron vanes placed within the energized coil become magnets with poles as shown, by reason of the direction of flow of the magnetic lines.
(F) Applying the above principles and having one vane stationary and one attached to the pointer shaft (free to move) it can be seen that as the vane on the shaft is repelled, it will move the pointer up-scale. The spring controlling the movement of the pointer brings the pointer to rest at a point where the electrical and mechanical forces balance.

shaft to turn, carrying the pointer over the scale. If vane *B* was free to turn with no retarding action, it would immediately assume a position 180° away from vane *A*. The retarding or controlling action of this instrument is supplied by a spring having approximately a straight-line characteristic. With both vanes in the same plane and magnetized by the same source, the resultant induced magnetism will change in strength as the square of the current in the coil. But as the moving vane is caused to move away from the stationary vane, the repelling force between the like poles varies inversely as the square of the distance between them. Thus, the fairly uniform scale distribution of this type of instrument is the result of the combination of the square and inverse-square characteristics of the operating element.

Operating Principle of the Induction Type

The induction principle of operation depends on the interaction of inducing and induced currents. It is desirable to have a "quadrature field" for the purpose, which we have in

form of a "space displacement." (Look up textbook if familiar with these terms; but the following gives the idea.) The current that flows in the primary coil magnetizes the iron core and magnetic lines flow around the core, across the air gap and core, and through each coil, as they are wound in such a direction as to have a mutual flux (see Fig. 4). The primary voltage induces a voltage in the secondary coils which are in series with the auxiliary coils as shown in Fig. 4. These auxiliary coils are wound in opposite directions and the flux flowing around them cuts the core at right angles with respect to the flux of the primary coils. The resultant of these two fluxes induces a voltage in the aluminum drum which will be in opposition to the inducing voltage causing the drum to move. The retarding action is obtained with a spring, and the action is electromagnetically damped by a magnet close to the drum.

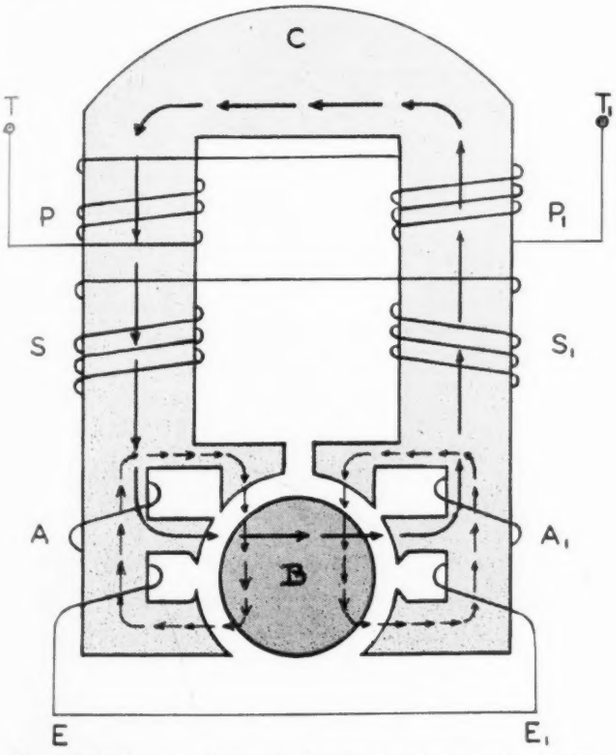

Fig. 4. Induction type instrument. Diagram showing operating principle and also construction features of the stationary element.

Construction of the Principal Types of A-c. Ammeters

Fig. 4 shows not only the operating principle but a typical stationary element of an *induction* type ammeter. Therefore we take up this type first. The stationary element consists of a set of primary coils P-P_1; a set of secondary coils S-S_1; and a set of auxiliary coils A-A_1 wound on a laminated iron cage C. The air gap between the laminated main core C and the soft iron core B is the space in which the moving element revolves. This moving element (not shown) consists of an aluminum drum mounted on a shaft, with hard steel pivots at each end of the shaft. The shaft also carries the pointer and three balance weight arms mounted 90° apart around the shaft. A phosphor bronze spring is used to control the movement of the pointer. The pivoted shaft moves between two sapphire jewel bearings, one at each end. A permanent magnet of high-grade steel, properly magnetized and carefully aged, is used for damping, by acting on the aluminum drum. (This damping magnet is not shown.) The induction type ammeter was made in both portable and switchboard types. Switchboard types were generally limited to measurements on one frequency only, while the portable types are calibrated and compensated to read accurately on the two power frequencies of 25 and 60 cycles. A calibration curve is usually supplied with the portable instrument, giving the actual current readings on the intermediate frequencies between 25 and 60 cycles.

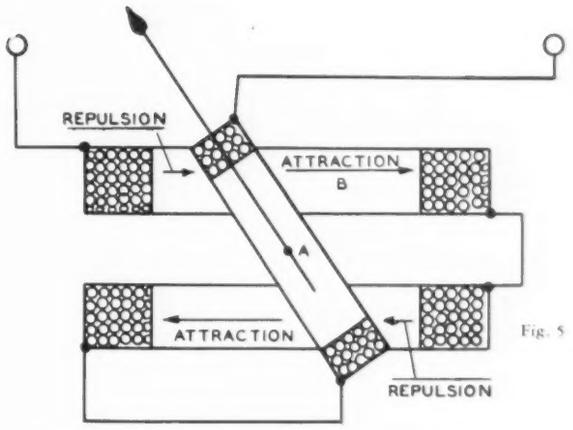

Fig. 5

A *dynamometer* ammeter mechanism consists of a moving coil A and a divided stationary coil C-B as shown in Fig. 5. These coils are interconnected as shown in Fig. 5 for milliammeters, and for higher capacity ammeters, the moving coil and stationary coil are connected in parallel. The moving coil is shown in its approximate position of zero when the coils are de-energized. An instrument spring, mounted on the moving coil shaft and anchored to a spring adjuster, is the controlling element of this type instrument.

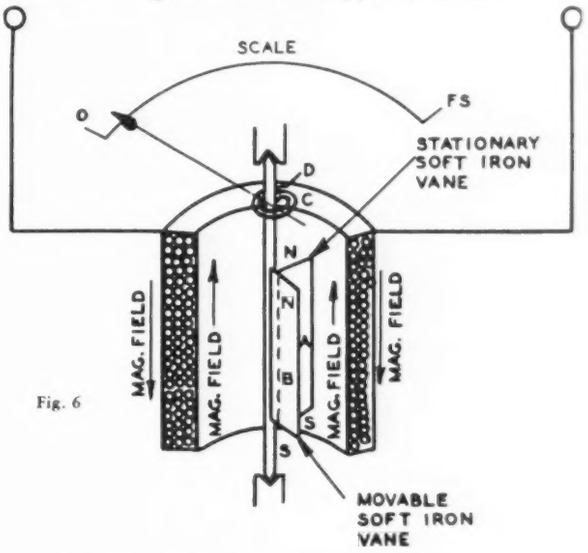

Fig. 6

The essential parts required for producing and controlling the pointer movement of a *repulsion* type instrument are shown in Fig. 6. These parts include the coil C, the two iron vanes A and B, and the spring D.

Ammeter Connections

Ammeter connections both internal and external are simple, but most important to service men when installing these instruments and when "shooting trouble." Typical internal connections of the three types discussed in detail in this chapter are shown in Figs. 4, 5 and 6. External connections are made in either of two ways, directly in series with the line as in Fig. 7A or through an instrument transformer as

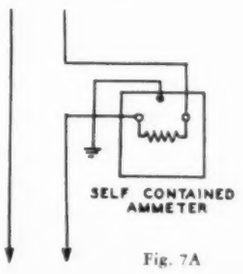

Fig. 7A

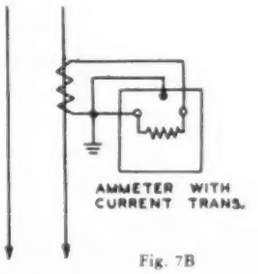

Fig. 7B

in Fig. 7B. It should be noted that the secondary circuits of all instrument transformers should be grounded to avoid high voltage stresses to ground.

Applications of the Three Types of Movements

The charts, Figs. 8, 9 and 10, are self-explanatory.

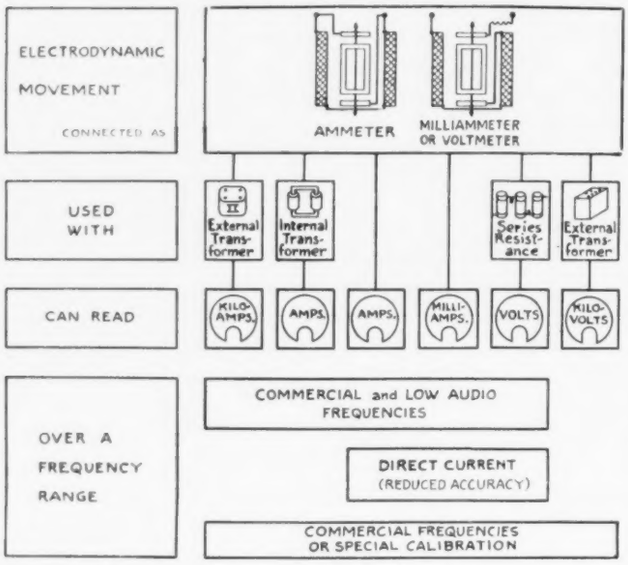

Fig. 8. Application chart for electrodynamometer type.

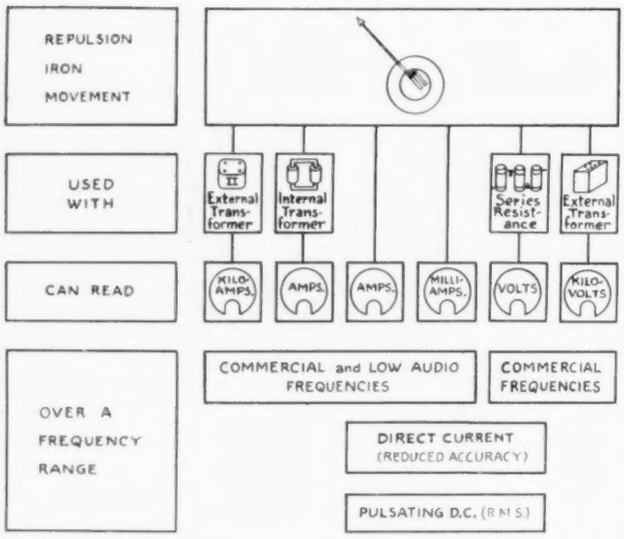

Fig. 9. Application chart for moving-iron type.

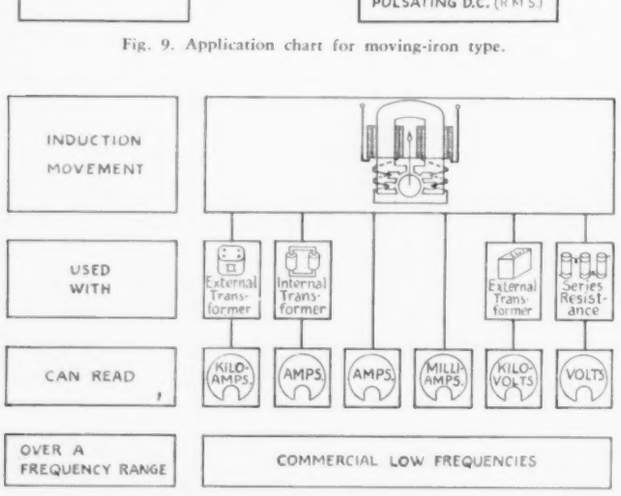

Fig. 10. Application chart for induction type.

SOURCES OF ERRORS

It was pointed out in the chapter on d-c. instruments that the sources of errors are divided into two general classes, mechanical and electrical. The "Possible Defects" chart, Fig. 11, indicates the causes and effects of errors in alternating-current instruments.

It has been found after many years of experience that the mechanical sources of errors are greatly in the majority. The causes and effects of instrument trouble as listed in the chart will be discussed later, after we have given thought to the methods of inspecting and adjusting the calibration of the various type a-c. instruments.

Symptom: Instrument Fails to Indicate

POSSIBLE DEFECT	
MECHANICAL	ELECTRICAL
Pointer sticking	Open coils
Element out of jewels	Open resistance
Pivots tight in jewels	Loose connections
Damping vane sticking	No external circuit
Damping disk lying on magnet	Shorted coils
Broken pivots	Opposite polarities in divided stationary coil
Coils sticking due to foreign matter between coils	Shorted transformer
Coils warped	Open in transformer winding
Loose wires	
Misplaced coil cement	
Cross arms caught on adjacent parts	

Symptom: Instrument Indicates Incorrectly

POSSIBLE DEFECT	
MECHANICAL	ELECTRICAL
Friction—Static or rolling	Poor connections
Sticking up scale	Grounds
Off balance	Partly shorted coils—series resistance or shunt
Spring convolutions touching	Reverse polarity (Wattmeter)
Bent pointer	Wrong connections
Zero shift	Open shunt
Spring set	Temperature error
Loose spring connections	External field effects
Loose pointer	Magnetized metal cases
Loose pivots	Steel panel mounting
Loose jewels	Frequency error
Pointer not passing full-scale or zero	Distorted coils
Too much or not enough end play	Field effects between elements
Dial or element shift	
Parallax	
Coils rubbing	
Damping vane rubbing	
Tail weight hitting zero adj. pin	
Pointer touching dial or glass cover	
Pointer shaft touching coil	
Spring touching adjacent parts	
Damping disk touching magnet	
Element shaft touching damping chamber cover	
Annealed springs	

Fig. 11. Trouble chart for a-c. ammeters and voltmeters.

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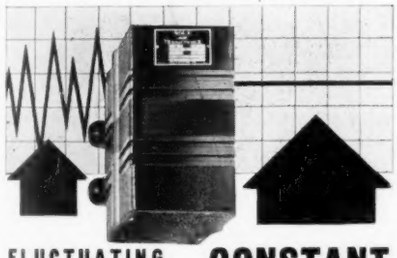

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TEST AND CALIBRATION

The overall test and calibration of any ammeter, whether it be at the factory or if repairs are made in the field, should follow the outline below.

Brief Outline

(1) A complete mechanical inspection consisting of checking all connections for tightness, adjusting balance, adjusting end play of moving element, checking clearances of moving parts, setting bumpers, checking operation of zero adjusters, inspecting springs for clearance of convolutions and bends, check deflection limits of pointer (above and below zero and full scale).

(2) Connect instrument to test circuit and check movement for polarity, response, damping and friction.

(3) By comparison with a standard of known accuracy connected to the test circuit, make calibration adjustment on the instrument under test and check all cardinal points on the scale.

(4) Clean instrument thoroughly and assemble cover.

(5) Recheck zero, balance, friction and scale calibration after closing instrument to be sure case-to-base assembly has not caused distortion or shifting of parts. Also at this point check the zero adjuster for movement of pointer above and below zero.

(6) Ground test, at voltage recommended by A.I.E.E. authorities for the particular type of instrument under test.

Detailed discussions of the above six features in the calibration and inspection of electrical instruments are given in other chapters. Nevertheless, a few points will be taken up now.

MECHANICAL

Assume that a new part such as a moving coil, spring, pivot or other vital item has been replaced or repaired. This calls for at least a partial dismantling of the instrument and hence a disturbance of the mechanical assembly. In this case, a mechanical inspection and mechanical adjustments are necessary before calibrating the instrument. Although all mechanical inspections and adjustments are important, there are three major items, namely balance, end play and spring effects that call for special attention.

Visual Inspection

Before any mechanical adjustments are made, a visual inspection should be made to see that all moving parts have good clearance, that connections are correct, that parts at different potentials are clear of each other and that the instrument is free of dust, lint, moisture or other foreign matter. All screws, nuts and other assembling devices should be checked and tightened if necessary. The pointer travel should be checked for sufficient deflection above and below scale ends, and bumpers if used should be set for proper position.

Springs

The springs of a dynamometer instrument are for the purpose of conducting current to and from the moving element, as well as for control of the element movement—which is the purpose in all types.

Instrument springs are rolled to correct proportions, formed so that convolutions are evenly spaced; and aged to relieve mechanical stresses and minimize hysteresis. They retain their stable characteristics with age and variations of temperature, and under load—but not if they are abused during servicing.

In use, spring ends—both of the inside convolution and the outside convolution—are fixed firmly either by soldering or by a mechanical means such as a clamp. The inner convolution is in most all cases soldered to a collet that is firmly attached to the moving element. The soldering of these small instrument springs presents a difficult problem. First it should be a good solder connection—not a loose connection, nor a cold solder job that will eventually break loose. To make a good solder connection, the surfaces should be clean, a good soldering flux should be applied to these surfaces and the iron should be hot enough to cause the solder to flow freely. The iron should not be held in contact with the spring too long as this will cause local annealing, and uneven elasticity of the spring will result. After soldering a spring it should be washed thoroughly in a good cleaning solution such as pure grain alcohol to remove any remaining soldering flux, oil or grease that might cause convolutions of the spring to stick together. When soldering or clamping the outside free end of the spring, be sure the spring is in the normal or no-torque position.

When spring changes are made that require bending, make bends with as large a radius as possible, as shown in Fig. 12. This will avoid cracking the exterior of the spring and introducing stresses that cause unstable characteristics. Incorrect bending or shaping of the anchored end of the spring likewise results in uneven spacing of the spring convolutions, causing the convolutions to touch when the spring is being worked. To avoid this trouble, after any spring adjustment, move the pointer of the instrument slowly from zero to full scale, noting the convolution clearances throughout the movement. Be sure also, while making the above check, that the spring amply clears all adjacent parts.

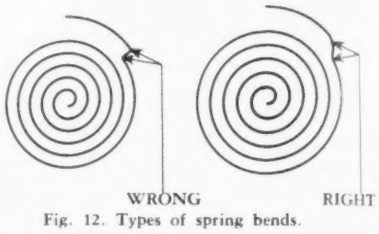

Fig. 12. Types of spring bends.

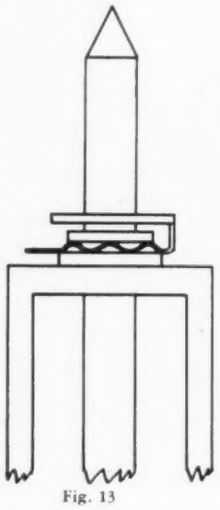
Fig. 13

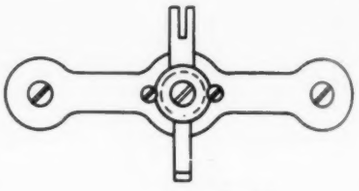
Fig. 14

Resetting Pointer on Zero

There are a number of methods used in resetting the pointer on zero after adjustments of spring, a few of which are: moving the complete element, shifting the lower spring adjuster, moving the slip spring collet on the shaft and shifting the top or spring contact side of a two-piece zero adjuster. These methods will be explained by discussing what to do after a spring adjustment has been made on a miniature repulsion type instrument. In this type instrument, the moving element may be a complete assembly, which is held in place by two set screws having large-radius heads. The screw heads cover a part of the bracket holding the movement. By loosening these two screws the complete movement assembly may be shifted. This is also a means of making calibration adjustments.

In instruments having upper and lower springs, the lower spring holder may be shifted, leaving the top spring holder (zero adjuster) centered to allow for correction of zero shift either above or below zero. The spring type collet or inside spring holder as shown in Fig. 13 is used in large switchboard type instruments. The collet is assembled to the shaft and held in place by a shoulder nut that compresses the collet as shown in Fig. 13. The compression of the collet is sufficient to hold the spring in place under operating conditions, but may be moved by a slight pressure applied to the tail piece of the collet.

The two-piece spring adjuster as shown in Fig. 14 is adjusted by loosening the screws holding the two pieces together and shifting the top half or spring (anchor end) to set zero. The lower part of this type of adjuster is positioned at right angles to the bridge of the element, and the screw is tightened. This gives the equivalent of a one-piece zero adjuster with the lower half at the mid-position to allow for correction of zero in either direction by movement of the adjuster button in the case.

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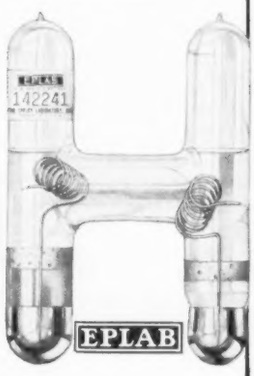

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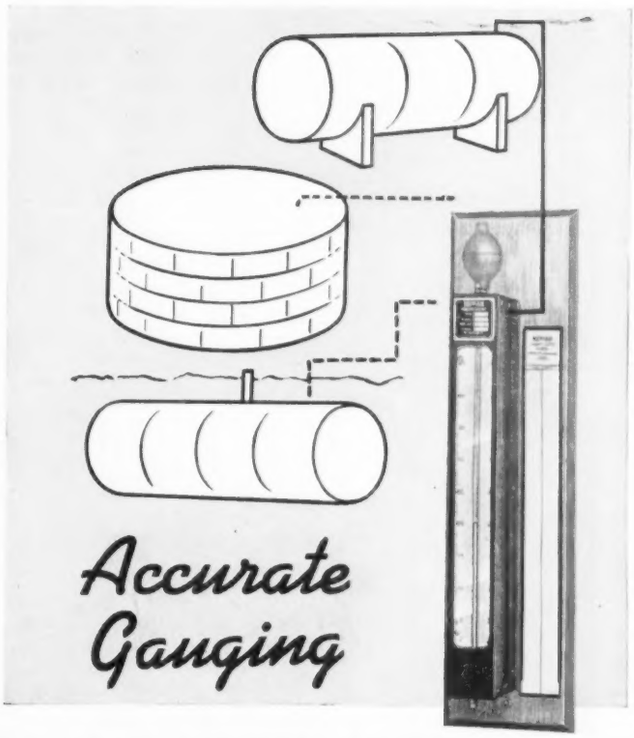

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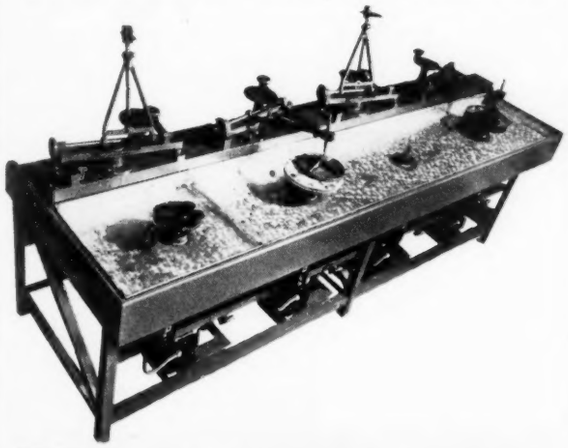

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Measuring Spring Torque

In the course of repair, or to change the capacity of an instrument, it may be necessary to supply a new spring. In cases of this kind, it is necessary to know the torque or force necessary to deflect the pointer to full scale. This information is obtained by hanging a small weight on the pointer until it is deflected to full scale with the pointer in a horizontal position as shown in Fig. 15. The distance *C* from this pivot to the center of the weight should then be measured in millimeters. The product of the weight in grams

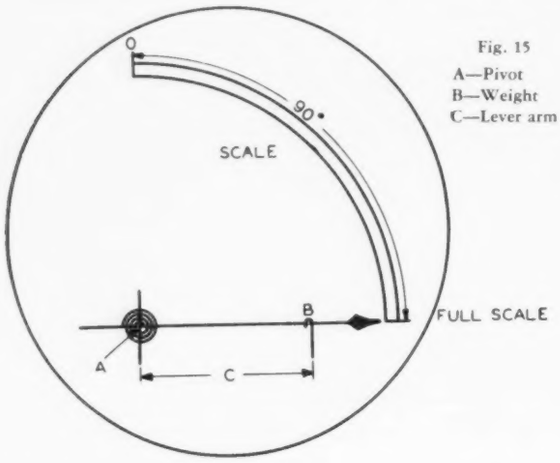


Fig. 15
A—Pivot
B—Weight
C—Lever arm

and distance in millimeters will be the torque in millimeter-grams for the angular deflection of the scale. Since spring torques are usually expressed for 360°, the torque for a 100° scale should be multiplied by 3.6 to arrive at the correct value for ordering a new spring from the manufacturer. Torque measured in inch-pounds may be multiplied by 718.8 to get the torque in millimeter grams. A piece of copper wire may be used as the weight and, if its weight cannot be measured on a laboratory balance, this weight in ounces can be had by referring to a wire table.

In instruments where the torque is proportional to the applied current, the above method may be used and simple multiplication or division used to calculate the degree of change necessary. Thus if the capacity is to be increased 10%, the spring should be 10% stronger or if the capacity is to be decreased 10%, the spring should be 10% weaker. In dynamometer type ammeters, the torque increases as the square of the current. In changing the capacity of these instruments, the torque is calculated as follows:

Assume we have a 5-amp. instrument and wish to change it to have a 6-amp. capacity. Let us say that the full scale (100°) torque is 5 mg. Then the torque at 5 amperes would be $(5)^2 : (6)^2 = 5 : x$

Solving this would give 7.2 mg. for 100° and the torque for 360° would be $100 : 360 = 7.2 : x$

Solving this we get 25.92 mg. or the strength to be specified when ordering the spring.

Since we stated that the torque changes as the square of the current, the above may be proven as follows:

Square the current capacity of the instrument, $(5 \text{ amps})^2$

Square the proposed current capacity, $(6 \text{ amps})^2$

Subtract the smaller from the larger $(6)^2 - (5)^2 = 11$

Divide the difference (11) by the capacity squared $(5)^2$ or 25

Solving, we get $11 \div 25 = 0.44$ or 44%, the change necessary to make the instrument read full-scale at 6 amperes.

If the spring torque is 5 mg. at 5 amps. then it would be 44% greater at 6 amps. or 1.44×5 mg. $= 7.2$ mgs. for 100°. For 360° the torque would be 3.6×7.2 mg. $= 25.92$ mg.

Balance Weights

The balance of a spring-controlled moving element is important initially as a means of helping produce good scale distribution and secondly as a tell-tale—as a means of indicating whether or not element parts have become deranged, causing calibration errors (usually indicated by an off-zero pointer position when the instrument is in the normal operating position). Setting the pointer back on zero and assuming the calibration of the instrument to be correct is one of the most common errors made by instrument users. Such procedure usually results in a change of scale distribution and hence a calibration error. Many times a zero shift of the pointer is blamed on spring set whereas incorrect balance is really the cause of the trouble. As a means of checking whether the balance is the cause of error, position the switchboard instrument horizontally (face up), set zero and recheck.

The proper balance positions were illustrated and explained in Chapter I, where Figs. 5, 6 and 7 showed the pointer in three different positions. If the pointer rests at zero when in these positions, the element is correctly balanced and therefore the calibration will not be affected by weight distribution of the moving element.

The tail piece and the cross arms are usually threaded or notched as a means of holding the balance weights in place.

Of the various kinds of weights used to balance instrument moving elements, the three illustrated in Fig. 16 have been successfully used for a number of years by the leading instrument manufacturers. Each of the three types, however, will give rise to balance troubles if not properly applied.

The split type balance weight (*A*) has a tendency to cut its own thread on the cross-arms if the split end is not properly set. The correct setting of this gap in the balance weight is when the split end is compressed to have an inside thread diameter slightly smaller than the outside diameter of the threaded shaft. With weights adjusted thus, they may be assembled to the shaft causing the split end to spring slightly and hold tightly, eliminating the possibility of shifting. Moving the weight back and forth on the shaft tends to undercut the shaft and cause a loose assembly, allowing the weight to shift with slight vibrations and change the balance.

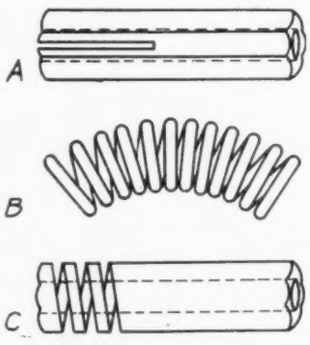
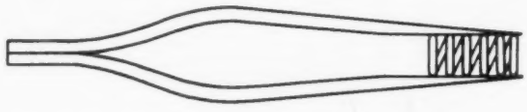


Fig. 16

Fig. 18

Fig. 17



The wire-wound type of balance weight (*B*) is most widely used in miniature type instruments. It is usually made of phosphor bronze wire wound helically on an arbor having a slight curve. While this is a desirable type to use if made and assembled correctly, it probably causes more trouble than the other types, due to incorrect use and improper assembly adjustments. The weight should have sufficient length to produce a good grip on the balance arm. If the weight is forced on or pulled off the shaft, there will be a tendency to shorten or lengthen the weight by causing a change of space between the turns. This altered length due to mechanical stresses tends to return to normal length as the stresses relieve themselves. This changes the relative position of the weight on the shaft and hence changes the element balance. To prevent changes of weight length, the weights should be *gripped full-length* with flat-ended tweezers (as shown in Fig. 17) and moved on the shaft while thus straightened.

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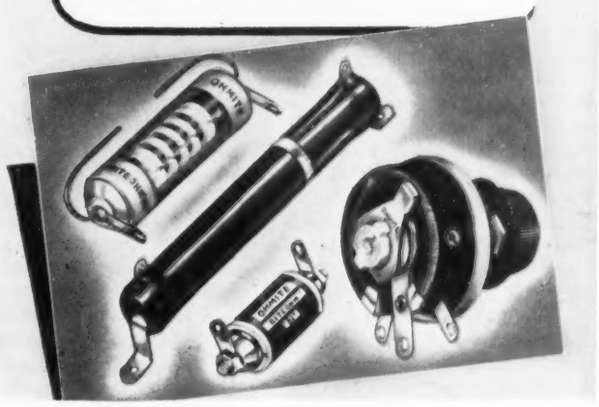

The third type of balance weight is of the lock-nut design, having a cut of about a turn and a half around the nut as shown in Fig. 16C. For its grip on the shaft this type depends on slight compression of the split end, where the few threads have a slightly smaller pitch than the thread on the shaft. Trouble may arise if the weight is compressed too much: the thread becomes too tight and this often results in broken shafts when a user forces the assembly of the weight. On the other hand, if the compression is insufficient, the result is a loose weight and balance errors due to weight shift. It will be seen that if the weight is correctly compressed it will allow for use of assembly and will hold tightly in position.

At this time it might be well to add a caution in the assembly of balance weights: Do not cement any weight to its shaft, as it makes future adjustments difficult.

End Play and Notes on Pivot Bearings

End play is the amount of end-to-end motion of the moving element shaft. The shaft ends are equipped with highly-polished steel pivots, accurately dimensioned as regards conic angle and end radius and hardened to stand shock and long wear. These pivots turn in highly-polished sapphire or diamond jewels with conic angle slightly larger than that of the pivot. The jewels are usually mounted in threaded jewel holders or screws (see Fig. 18). With this arrangement, the position of the jewel may be adjusted so that the end-to-end motion of the element shaft is accurately set (see Fig. 4 in Chapter I).

End play is usually gaged for correctness of set, by checking the *side play* of the element. By reason of the relative angles of the pivots and jewels, the side play is several times greater than the end play, so that the method is convenient.

Great care should be exercised in making end play adjustments so that the jewel and the pivot are not forced in contact with each other. This usually causes flat pivots as the pivot is softer than the jewel. To avoid bringing the jewel down tight against the pivot, the pointer should be continually moved back and forth along its length while the jewel screw is being adjusted. See also Fig. 3 in Chapter I on direct-current instruments, and the accompanying notes on end play.

ELECTRICAL TEST

The next step in the test of an ammeter is to make electrical connections and check the action of the movement. A polarity check to ascertain that the pointer has a forward motion when current is applied is a natural first electrical test. Since it is only possible to assemble the repulsion movement vanes one way, there is no reason to expect reverse polarity in the repulsion-iron type of instrument. In the dynamometer movement, however, there is a possibility of reverse polarity by reason of the relative connections and position of the moving and stationary coils. It can be seen from Fig. 5 that the stationary coils and the moving coil are positioned at approximately 45° apart. Coil connections are such that the moving coil is repelled by the fields of one side of the stationary coils and attracted by the fields of the other side. Therefore, if the connections of the moving coil were reversed, the deflection of the pointer would be backwards. A like condition would also occur if the stationary coils were connected in reverse. If only one of the stationary coils had reverse connections, the fields of the two would be neutralized and little if any pointer movement would be noted. When too little deflection is noted, however, do not immediately attribute the cause to opposing stationary coils; other causes (shorted coils, open coils, shorted transformers, no external circuit, etc.) may be responsible.

To detect friction or sticking an electrical check may be made as follows: Energize the movement, applying and reducing the current gradually, causing the pointer to move up and down scale as slowly as possible. At various points on the scale hold the current steady; note the position of the pointer and tap the instrument lightly. If any noticeable change takes place in the position of the pointer, friction exists at that point. The amount of friction allowable (if any) will be dependent on the type of instrument under test. As a suggestion, it would be unwise to dismantle an instrument of the one percent accuracy type to correct a frictional condition amounting to a small fraction of the allowable accuracy. This recommendation is made because the writer has witnessed this pratice (or malpractice!) many times while in the field. If sticking or an objectionable amount of friction is present, the instrument should be opened and corrected as outlined under the heading of friction in the discussion of possible errors.

AMMETER CALIBRATION ADJUSTMENTS

The calibration of an ammeter is checked by connecting a standard of known accuracy in series with the instrument under test, and comparing readings. If full-scale, zero and all cardinal points check with those of the standard, no adjustments are necessary. If the scale does not check and is either equally high or low on all points, adjustments should be made to correct the full-scale point, which should also bring the other points in line. If the calibration errors of the main points are not in the same direction, a new dial should be marked after making full-scale adjustments, or a correction curve should be used.

Calibration adjustment methods vary with the different makes of ammeters. Among these methods are: altering the spring strength; changing the resistance of a shunt across the terminals; and (in moving-iron ammeters) adjusting the relative positions of the iron vanes.

Since spring adjustments were explained in detail earlier in the discussion, it will suffice to say that increasing or decreasing the spring strength changes the pointer indications over the scale. At this time, however, it is well to keep in mind that when spring changes are made in order to change the capacity of the instrument, care must be taken not to overtax the coil capacity. When lowering the capacity of the instrument, it should also be understood that too weak a spring might cause an unsatisfactory result due to friction.

In the case of moving-iron instruments there are several different methods used in changing the relative positions of the iron vanes for making calibration adjustments. The object in all cases, however, is to change the distance between the vanes in the no-load position so that the force between the two vanes when magnetized will be altered. The reason is that like poles repel each other and the repelling force varies as the square of the distance between them. One method of varying the positions of the vanes is to rotate the complete element. This changes the zero position of the pointer. Since the pointer and moving vane are on the same shaft, resetting the pointer on zero changes the position of the moving vane with respect to the stationary vane. Strengthening or weakening the spring to reset zero also allows for further adjustments where the element rotation method is used.

Another method of changing the relative positions of the vanes is possible where the stationary vane is mounted in a bracket free to move by screw adjustment. With this adjustment the stationary vane may be moved by adjusting the screw in or out until the full-scale indication of the pointer checks with that of the standard.

Still another method of vane movement is possible where the stationary iron is in the form of a wire rod and is mounted in a cam-like screw. As the screw is turned the position of the stationary iron is moved by reason of its position in the cam. This adjustment may be made from the rear of the instrument without removing the instrument cover.

The shunt method of calibration adjustment is to have a resistance or shunt connected across the terminals of the instrument. Shunts should be made of the same material as the coil (usually copper) to avoid temperature errors. Since the electrical forces of the instrument depend on the current in the coils, and since a shunt takes a portion of the current to be measured, it can readily be seen that the shunt resistance controls the current that flows in the coils. The shunt may be in the form of a resistor spool, resistance card or a flat strip. In any case, increasing the resistance of the shunt increases the current flow in the coil and thereby causes the pointer to read higher on the scale. The reverse condition is true when the resistance of the shunt is lowered. Removing

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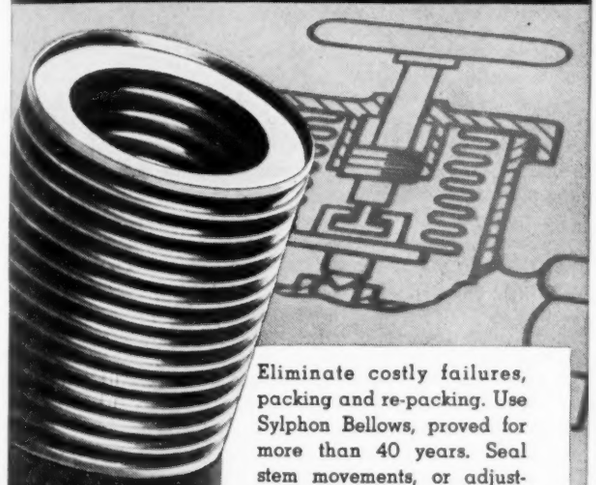

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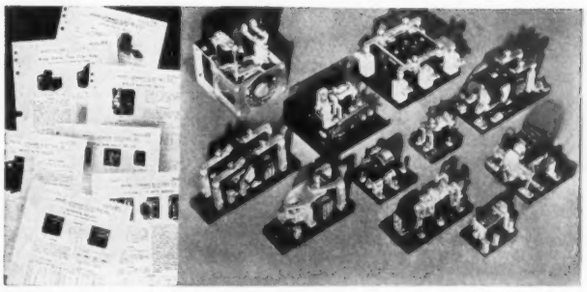

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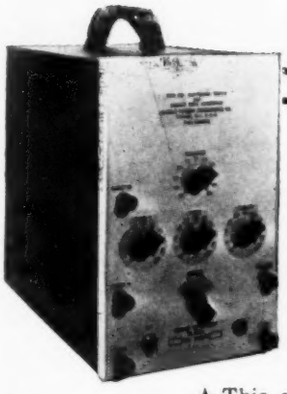

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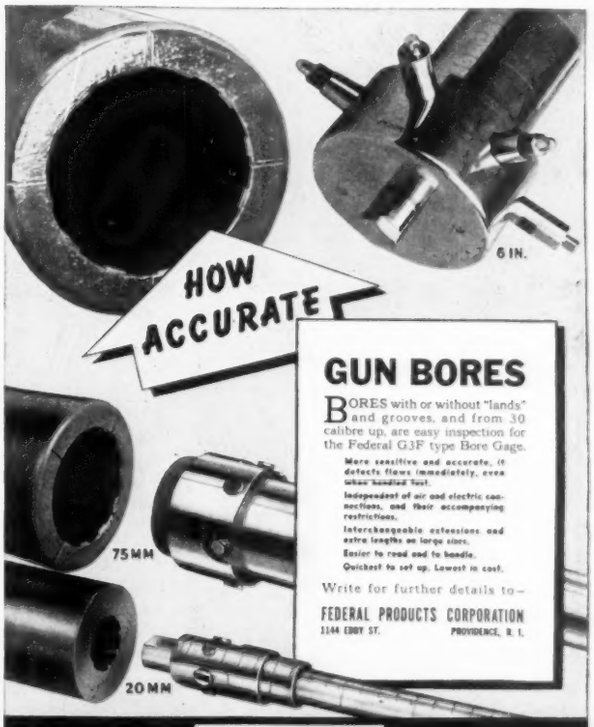

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wire from the shunt card or spool reduces the shunt resistance and causes the pointer to read lower. Adding wire to the spool or card increases the resistance and hence allows more current to flow in the coils, giving a pointer indication higher on the scale. Filing a shunt strip removes material and increases the resistance of the shunt. A temporary adjustment to decrease the resistance of a shunt strip is to add solder to the strip with a hot soldering iron.

The switchboard form of standard ammeter is initially calibrated in the vertical position. For greatest accuracy it should be mounted and used in this position. The portable form of standard ammeter is calibrated in the horizontal position (face up) and may give slightly inaccurate indications if used otherwise.

Due to its high initial and permanent accuracy and its long open scale (320° to 340°), the portable form induction type ammeter is a desirable instrument to use as a standard for checking other instruments on its calibrated frequency. Before using this type of instrument for checking purposes, it should be left on the circuit about ten to fifteen minutes to allow for self-heating.

CONSTANT-CURRENT SOURCE

A steady electrical supply plays an important part in the testing and checking of electrical instruments. Some sort of a current stabilizer should be used in ammeter calibration work. The current stabilizer* is a device that allows for a considerable change in line voltage without allowing a change in the predetermined value of output current. Its construction is simple, the equipment being mounted on a flat base board. Twelve lamp sockets are required and sufficient wire to connect the device as shown in Fig. 19. Five 25-watt tungsten lamps, and two 175-ohm non-inductive resistors constitute the bridge arrangement. A 100:5 current transformer with a variable resistor connected as shown in Fig. 21 completes the equipment necessary to build the device.

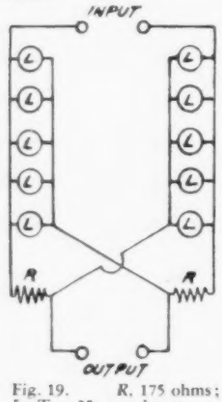

Fig. 19. *R*, 175 ohms; *L*, Ten 25-watt lamps.

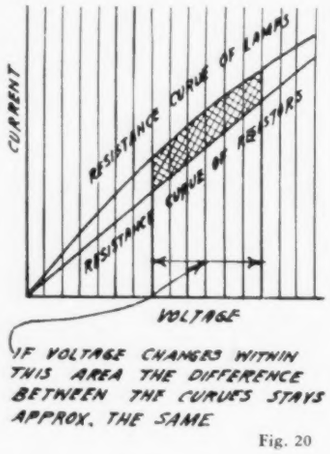
CURRENT
RESISTANCE CURVE OF LAMPS
RESISTANCE CURVE OF RESISTORS
VOLTAGE
IF VOLTAGE CHANGES WITHIN THIS AREA THE DIFFERENCE BETWEEN THE CURVES STAYS APPROX. THE SAME

Fig. 20

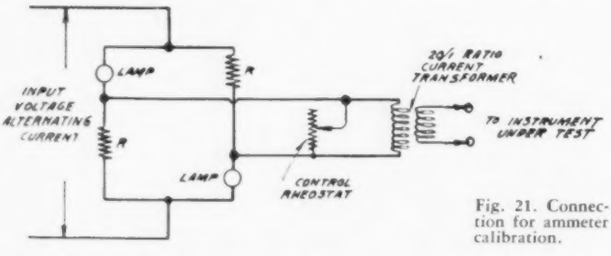

Fig. 21. Connection for ammeter calibration.

The current stabilizer operates on the well-known bridge principle, making use of the non-inductive resistors in two of the arms and a bank of lamps in each of the opposite two arms of the bridge. As the Wheatstone bridge depends on the fact that there is no current flow between two points of equal potential, so the current stabilizer makes use of the fact that a steady current will flow if the difference of potential between these two points does not vary. Likewise, as the galvanometer of the Wheatstone bridge does not move under balanced condition, so the output of the current transformer connected across the diagonal of the bridge of the stabilizer does not change. Characteristic curves taken on a device of this kind are shown in Fig. 20. From these curves it will be noted that the resistance of the resistor arms remains constant under all values of voltage. While the resistance of the lamps varies, however, the potential across the diagonal of the bridge remains constant between 70 and 130 volts. It is between these values of voltages that the stabilizer operates efficiently. As the ratio of all four arms remains constant between these values, it can readily be seen that the potential across the diagonal of the bridge will not vary unless the load is changed. Therefore, with no change in voltage across the transformer the current in the secondary is constant. The current setting will remain constant unless the voltage across the bridge rises or falls outside the 70-130 limits. In test for calibration purposes the current is changed to different values by manipulating a variable resistor connected across the primary of the transformer.

This device is used as a supply to calibrate and check various types of ammeters. It is capable of operating several standard type switchboard instruments at one time. However, by varying the combinations of resistors and lamps the stabilizer can be made other capacities.

Current stabilizers should be used primarily for the purpose of insuring instruments of greater accuracy; and secondarily to protect operators from eye strain or fatigue due to reading instruments where unsteady current causes the pointer to oscillate. Two operators are required to calibrate: one to read the standard and the other to check the instrument under test.

SUGGESTIONS ON INSTALLATION OF SWITCHBOARD AMMETERS

Before mounting an instrument (even a new one) on a switchboard, check the zero position of the pointer and the three balance positions. The zero position of the pointer may have changed due to shock in transportation from the supplier. Practically all modern instruments have an external means of resetting the pointer on zero.

All switchboard instruments are calibrated in a vertical position unless otherwise specified. For greatest initial and permanent accuracy, the instruments should be mounted and used in the vertical or calibrated position. (Instruments designed for built-in use on sloping panels have presumably been calibrated in their intended sloping position.)

Before connecting an ammeter in a line, check its rating to be sure of proper application. The coil rating of an ammeter is given as the amount of current which the coil will carry continuously without damage to the coil and which will move the pointer to the full-scale position. If the full-scale marking is greater than the coil rating, a current transformer having a ratio equal to the ratio of the scale marking to the coil rating should be used.

An instrument should never be used on a circuit of higher voltage than its insulation rating.

The switchboard or instrument mounting should be free of vibration and located where abnormal temperature changes do not occur.

Most of the present-day switchboard ammeters have iron or steel cases that magnetically shield the element from stray fields. If the element is not shielded in this manner, a careful check should be made to ascertain that the instrument is not within the effective field of current-carrying conductors or other magnetic-field-producing elements. Unshielded instruments should not be used on steel panels, unless calibrated for the same.

While instruments are being installed or after they are mounted on a switchboard, there are many do's and don't's to be observed to avoid personal injury or injury to the instrument. A few of these items are outlined below.

Do not open secondary of current transformers until instrument connections are made, for reasons as stated before.

When making or breaking connections on a live board, use tools with insulated grips, work with one hand, stand on some insulating material and use rubber gloves when possible.

*A Current Stabilizer for Instrument Calibration, James Spencer. *Instruments*, May 1933, page 93.

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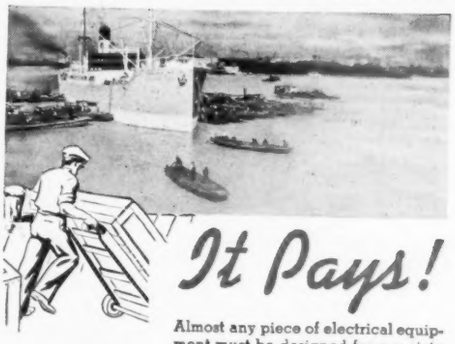

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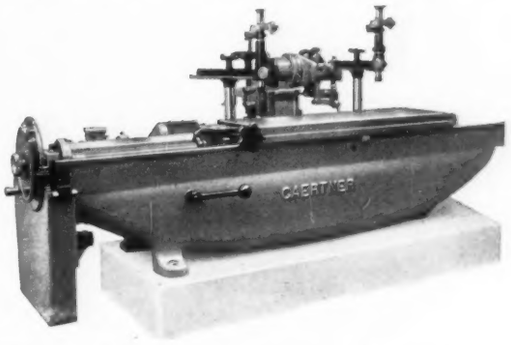

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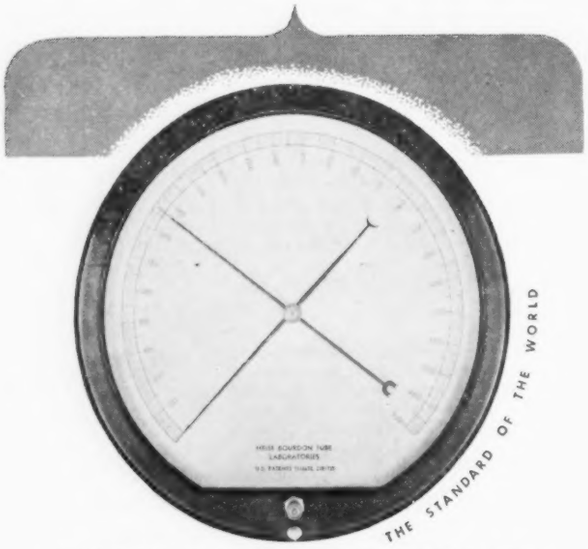

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Do not hammer, drill or cause vibration on switchboards after instruments are mounted. This reduces the life of pivots and jewels, loosens terminal connections, etc., introduces friction in the mechanism and many other faults that affect the initial and permanent accuracy of the instruments.

If for any reason it is necessary to remove the cover of an instrument, replace it as soon as possible to prevent foreign matter from getting in the mechanism.

After the instrument has been mounted on the board, it should be set on zero and checked for free operation by running the pointer up and down the scale *slowly* to detect any friction or sticking.

When the ammeter has been installed, connect a standard of known accuracy in series with it and check calibration. This should be done for the purpose of finding any calibration errors that may be present by reason of misapplication, distortion of parts due to mounting, external field effects, etc.

As few switchboard instruments have antiparallax provisions, it is well to give consideration to the place and position of mounting the instrument to minimize possible parallax errors. Wherever possible, the instrument should be mounted at the average eye level of the various checkers. Provisions should also be made so that the checker may get close enough to the instrument to have good clear view of the pointer and scale markings. If these conditions are met, the observer will be able to focus his eye directly over the pointer and correct scale position, eliminating parallax errors.

Proper lighting is also important where accurate readings are desired. Insufficient light, bright glaring light or lights reflected in the glass cover are a few of the illuminating problems to be studied when installing an instrument. These possible causes of errors can be eliminated by proper exterior illumination, indirect illumination within the instrument, or the use of antiglare glass in the cover of the instrument.

PERIODIC CHECK OF SWITCHBOARD AMMETERS

While detailed checks of switchboard instruments cannot be made as often as possible due to continuous service requirements, etc., a quick check may be made periodically (at least every two months) as follows.

Check the external connections for tightness, to eliminate heating and high resistance contacts.

See that the pointer returns to zero when the instrument is de-energized. This also gives a fair indication of any change of balance (explained earlier).

As a check for calibration and friction, run the pointer up and down the scale slowly, *stopping* at various points on the scale, checking the indications against a standard of known accuracy. At each point, tap the instrument lightly to see that the pointer does not change its position. If varying calibration accuracies are noted throughout the scale, a probable cause is an unbalance of the element.

Tighten all case-to-base screws to insure good dust-proofing and clean the outside of and around the instrument.

Where auxiliary equipment such as transformers, resistors, reactors, etc., are used, be sure they are in good condition and connections are properly made.

REQUISITES FOR GOOD SERVICING

The five conditions outlined below should prevail if proper service or repairs are to be successfully accomplished.

(1) A light, clean room with sufficient bench space for making test or repairs.

(2) The service man should have a working knowledge of the construction and operating principle of the instrument to be serviced and be able to apply this knowledge in this work.

(3) There should be adequate and proper tools available for doing the work.

(4) Accurate standards or comparators should be available to make continuity tests, calibration checks and resistance measurements.

(5) Replacement parts should be available or the service department should be equipped to make these parts.

(To be continued)

MANUFACTURERS' NEW LITERATURE

In this department we report ALL pieces of NEW literature pertaining to Instrumentation, received from the manufacturers. Readers may secure without cost (unless noted) any or all items reported here, by filling out and mailing the card.

I-299 **Mechanical Meters — Flow and Liquid Level.** Catalog 2204, 8″ × 10½″, 16 pages, describes and illustrates meters for indicating, recording and controlling, contains schematic diagrams showing special applications of flow and liquid level meters and general mounting dimensions. The Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-300 **Gage Blocks and Accessories.** Forms 7393 & 7393-1, 3¾″ × 8½″, each 6 pages describe and illustrate Set No. 1 consisting of 81 blocks—120,000 different gage sizes in steps of 0.0001″, from 0.200″ to more than 12″; Set No. 2 consisting of 35 blocks, will make 80,000 different size gages in steps of 0.0001″, from 0.300″ to more than 8″. Johansson Division, Ford Motor Co., Dearborn, Mich.

I-301 **Information for Maintenance Men.** Publication GES-2820 through 2824, 3″ × 5″ cards, contain tables on bare stranded annealed copper cable data, motor wiring—standard speeds, wire and cable data, metric and decimal equivalents of common fractions and prony brake test formula. General Electric Co., Schenectady, N. Y.

I-302 **"C-D Capacitor."** Vol. 5, No. 6, 16 pages, contains articles entitled "Biasing Methods" and "Capacity Measurements" and department on radio service hints. Cornell-Dubilier Electric Corp., New Bedford, Mass.

I-303 **Vibro-Insulators.** Catalog Section 7900, 8½″ × 11″, 12 pages, is devoted to general discussion of the vibration insulation problem, gives methods of selecting proper vibro-insulator mounting together with methods of mounting and shows applications of mountings on various types of equipment. The B. F. Goodrich Co., Akron, Ohio.

I-304 **Electric-Type Temperature Controllers.** Bulletin 579, 8″ × 10½″, 8 pages, describes and illustrates controllers for all types of fuel: gas, electric and oil for automatically controlling temperatures from —60°F. to 1000°F. in ovens, smoke houses, cyanide pots, oil tempering baths, molten metal furnaces, plating tanks and on bearing temperatures. The Bristol Co., Waterbury, Conn.

I-305 **Dosage Meter.** Circular "F", 8½″ × 11″, 2 pages, covers safety device for protection of workers using radium and radium luminous material, indicating gamma-ray intensity and locating lost or misplaced radium. Geophysical Instrument Co., 1315 Half St., S. E., Washington, D. C.

I-306 **Electrical Instruments.** Folder ENT (3) 680-741, 10½″ × 15¼″, 12 pages, describes and illustrates applications of "Micromax" pyrometers, Homocarb electric carburizing furnace, optical pyrometers, pneumatic controllers, galvanometers and dynamometers and other instruments in metals, oil, ceramics and process industries, power plants, research and testing. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

I-307 **General Radio "Experimenter."** August 1941, 6″ × 9″, 8 pages, contains articles entitled "Impedance Bridge Assembled from Laboratory Parts—Part II" and "The Type 757-A Ultra-High-Frequency Oscillator." General Radio Co., 30 State St., Cambridge, Mass.

I-308 **Smoke Controls—Combustion Indicators.** Bulletin, 8½″ × 11″, 6 pages, describes and illustrates smoke alarms and recorders and combustion indicators. Boiler Room Equipment, Inc., 45 West 45th St., New York City.

I-309 **Dehydrator-Water pH Recorder.** Bulletin N-96-R-702(A), 7¾″ × 10½″, 8 pages, describes "Micromax" pH recording equipment for dehydrator water; gives illustrations of typical applications. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

I-310 **Furnace Pressure Controller.** Bulletin 742, 7¾″ × 10½″, 8 pages, gives description of control system and of parts that make up system, such as indicating controller, power cylinder and diaphragm motor; includes photographs of unit and schematic diagram and applications in various industries. The Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-311 **"Draft—What, Where, How and Why."** Publication No. 41-472, 8⅜″ × 10¾″, 20 pages, discusses measurement with the draft gage—where to measure, where to connect draft gages on various types of fuel and shows installations in various applications—by W. H. Pugsley, Mgr. of Engineering, The Hays Corp., Michigan City, Ind.

I-312 **Air-Operated Controllers.** Catalog 4051, 8″ × 10½″, 32 pages, describes and illustrates "Free-Vane" controllers for temperature, steam, flow, liquid level, pressure, draft, humidity and pH value. The Bristol Co., Waterbury, Conn.

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I-317 **Strip-Chart Recorders.** Bulletin 570, 8″ × 10½″, 16 pages, describes and illustrates d-c. ammeters, milliammeters, voltmeters, millivoltmeters, pressure gages, liquid level gages, recording thermometers, tachometers, flowmeters, mechanical motion recorders and Metameter system of telemetering. The Bristol Co., Waterbury, Conn.

I-318 **Thermocouple Data Book & Catalog.** Bulletin No. S2-3, 8½″ × 11″, 32 pages, covers complete line of thermocouples and thermocouple accessories, thermocouple wire, lead wire, heads, connectors, plug and socket assemblies, insulators and protecting tubes. Wheelco Instruments Co., Harrison & Peoria Sts., Chicago, Ill.

I-319 **Works Measuring Microscope.** Folder, 8½″ × 11″, 8 pages, describes and illustrates Cooke portable microscope for use in machinery and instrument plants —in workshops, tool and inspection rooms and in the laboratory. The R. Y. Ferner Co., 131 State St., Boston, Mass.

I-320 **Alnico Damping Magnet.** Booklet GES-2764, 7″ × 10¼″, 16 pages, is devoted to the story of the new damping magnet for GE watthour meters. General Electric Co., Schenectady, N. Y.

I-321 **Air Operated Controllers.** Catalog No. 8903, 7⅞″ × 10½″, 36 pages, describes and illustrates controllers for temperature, pressure, flow, liquid level and humidity and accessories; includes general mounting dimensions. The Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-322 **Timers.** Bulletin No. 146, 8½″ × 11″, 8 pages, covers synchronous welding timer, processing timers, seam-weld timer and the clutchless, repeat-or-non-repeat, delayed action timer. National Time and Signal Corp., 600 E. Milwaukee Ave., Detroit, Mich.

I-323 **"Automatic Combustion Control and Its Relation to Lower Steam Costs."** Publication No. 40-448, 8½″ × 10¾″, 20 pages, is entirely devoted to discussion of automatic combustion control — by Wm. H. Pugsley, Mgr. of Engineering, The Hays Corp., Michigan City, Ind.

I-324 **Gas Stethoscope.** Circular, 8½″ × 11″, 4 pages, describes, illustrates and prices stethoscope for the location of gas leaks in butane systems as well as natural gas. E. R. Gilmore, Box 5718, Homewood Station, Pittsburgh, Pa.

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I-328 **Voltage Relays.** Catalog Section 41-291, 8⅜″ × 10⅞″, 8 pages, covers features, construction and operation of relays to protect 115- to 460-volt, 60-cycle circuits or apparatus against voltage changes of any predetermined value. Voltage-time curves, wiring diagrams and outline drawings included. Dept. 7-N-20, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

I-329 **"The ABC of CO_2."** Publication No. 41-452, 8½″ × 10⅞″, 12 pages, contains discussion of CO_2, its measurement by hand and by machine and typical case stories of savings through increasing CO_2 percentage—by W. H. Pugsley, Mgr. of Engineering, The Hays Corp., Michigan City, Ind.

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I-331 **Vertical Comparator.** Publication No. 886, 6″ × 9″, 12 pages, describes and illustrates the Cooke Opticator and the vertical comparator stand for indicating by optical means differences of length by comparison with a master. The R. Y. Ferner Co., 131 State St., Boston, Mass.

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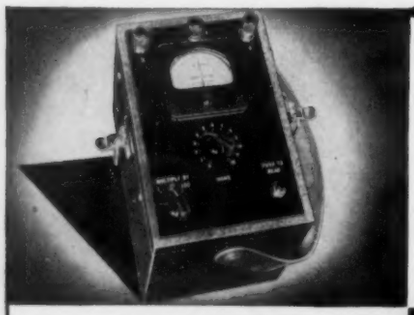
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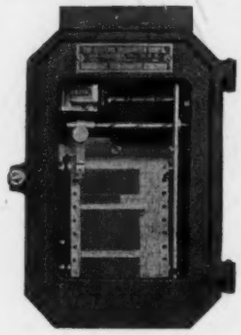
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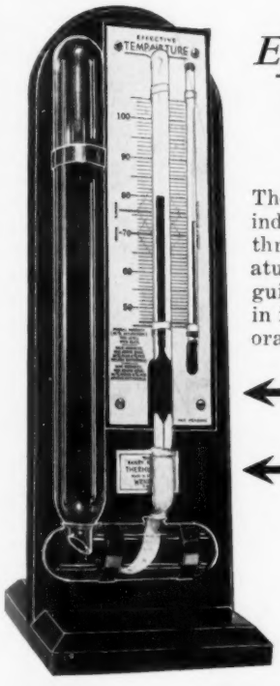

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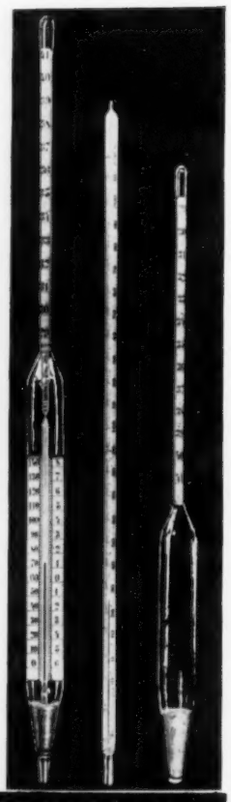

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Chicago Society for Measurement and Control

PROGRAM, 1941-42

October 13—"The Modern Differential Type Flow Meter."
Speaker—Dr. L. Spink—The Foxboro Company, Foxboro, Massachusetts.
Technical Chairman—C. J. Geiser.

November 10—"The Economic Value of Power Plant Instruments."
Speaker—Mr. J. R. Michael—Assistant Superintendent, Commonwealth Edison Company. Chicago, Ill.
Technical Chairman—J W. Murphy.

December 8—"Electronic Pyrometry."
Speaker—Mr. C. O. Fairchild—C. J. Tagliabue Mfg. Co.
Technical Chairman—Phil E. Cary.

January 12—"Automatic Control Valve."
Speaker—Dr. C. E. Mason—Mason-Neilan Regulator Co.
Technical Chairman—R. P. Sunderland.

***February 9—"Value of Instrumentation In a Modern Oil Refinery."**
Speaker—Mr. Vaughn Ischie—Sinclair Refining Co., East Chicago, Indiana.
Technical Chairman—W. Brock.

March 9—"Instruments Used In Artillery Fire Control."
Speaker—Dr. T. A. Cohen—Wheelco Instruments Co.
Technical Chairman—Mr. R. N. Powell.

April 13—"Symposium on Analysis Instruments Including
1—X-Ray Defraction Analysis.
2—Infra-Red Analyzing Equipment.
3—Spectroscope Analysis of Elements."
Speakers on each of these subjects to be announced.
Technical Chairman—Mr. H. A. Hulsberg.

May 11—"Instruments Used In Precision Machine Shop Practice."
Speaker—President of Acme Industrial Company of Chicago, Ill. With Discussion by Lieutenant Eisendrath, Director of U. S. Government Gauge Laboratory at Armour Research Foundation, Chicago, Ill.
Technical Chairman—Mr. L. A. Baudoin.

**At Phil Smidt's. Others at St. Clair Hotel.*

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To readers in PITTSBURGH and vicinity

American Society for Measurement and Control

OCTOBER MEETING Monday evening, October 13
MELLON INSTITUTE, 8 P.M.

"Control of Furnace Atmospheres"
Speaker—JOHN R. GIER, Jr., Ferrotherm Corp.

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In our Illuminating Laboratory, where the candlepower of searchlights, floodlights, and streetlights is measured, the photometric measuring device consists of a combination of light cells and a galvanometer.

When measuring beam candlepower, the light beam is directed upon a collecting device composed of light cells which convert light energy into an electric current. This current, which is directly proportional to the light intensity, is transmitted to a sensitive galvanometer, the scale of which is calibrated in foot-candles. Thus, it is possible to obtain quickly and accurately the many readings needed to determine the light-distribution pattern and the beam candlepower.

The light cell is also the basic element in several other G-E light-measuring instruments: the light meter, used to measure light intensities in homes, offices, and factories; the exposure meter, used in photography; and the luximeter, used primarily to determine the degree of pasteurization of milk.

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